Tropical Rainfall Measuring Mission (TRMM) 60 Day In-Orbit Performance Evaluation Report

April 1998

Executive Summary

The TRMM Observatory was launched on November 27, 1997 at 06:27 JST from Tanegashima Space Center (TnSC), Japan, aboard an H-II rocket. The launch and early-orbit operations went exceptionally well. Shortly after separation, the spacecraft solar arrays and high gain antenna were successfully deployed. The attitude control subsystem then stabilized the spacecraft in Sun pointing mode. The remaining early operations proceeded in accordance with the checkout plan and by day 5, the spacecraft evaluation was successfully accomplished. By day 12, the observatory was at mission altitude and instrument checkout proceeded on schedule. By day 60, the instruments were fully operational and collecting science. The TRMM Science Data and Information System (TSDIS) was receiving and processing the science data and spectacular science images were being produced.

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Acknowledgment

The success of TRMM addressed in this report is largely due to the skill, hard work, and dedication of an outstanding government/supporting contractor team, one of the finest that I have been associated with. In achieving this team success, several organizations have contributed significantly. I would like to take this opportunity to acknowledge and express my appreciation to those organizations who made the success of TRMM possible. These organizations are listed on the following page.

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Goddard Space Flight Center
- Flight Projects Directorate
- Engineering Directorate
- Mission Operations and Data Analysis Directorate
- Earth Sciences Directorate
- Office of Flight Assurance
- Management Operations Directorate
- Earth Sciences Program Office

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- Hughes Space and Communications
- TRW

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Langley Research Center
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Toshiba (NASDA)

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1. Document Overview

This report documents the TRMM Observatory activities from Launch through Launch plus 60 days. Section 2 describes the overall system performance of the Observatory. Section 3 provides an overview of the science data that was collected during the first 60 days. Section 4 describes the Flight Operations, including the interfaces with the Network Control Center (NCC) and the Flight Dynamics Facility (FDF). Ground System operations, including Distributed Active Archive Center (DAAC) and TRMM Science Data and Information System (TSDIS) operations, are discussed in section 5. Sections 6 and 7 discuss each subsystem and instrument, respectively.

Appendices A and B contain summaries of the 'Launch + 60' days anomaly and event reports, respectively, along with their current status. The anomaly and event reports are referenced within this document with the word Anomaly or Event, and includes the report number (ex. Anomaly #12). The reports are maintained in the TRMM Control Center in Building 32. Appendix C shows the current configuration of the spacecraft. The configurations at launch and at 14 days after launch were presented in the 14 day report. Appendix D lists all of the tables that have been loaded to date, with an explanation for each update. Appendix E contains supported plots that are referred to in specific subsystem sections. Appendix F contains the Acronym List.

Unless noted, all times are in UTC (GMT).

1.1 Introduction

The TRMM Observatory was launched on 97-331 at 21:27:00 from Tanegashima Space Center (TnSC), Japan, aboard an H-II rocket. TRMM's companion payload was ETS-VII. TRMM was placed into a 35° inclined orbit with an altitude of approximately 378 km. During days 7 through 11 after launch, TRMM performed a total of eight descent burns in order to reach the nominal mission altitude of 350 km. At that time, all instruments were powered on and gathering science and calibration data, except for VIRS, which was still in the cooler outgassing process. TMI and LIS were gathering science images and processing data beginning on 97-335, while CERES and PR were performing instrument checkout activities.

The spacecraft launch and early-orbit operations went exceptionally well, and there were no significant problems with any observatory components. The initial instrument check-outs also were accomplished successfully, with no major problems reported. The instruments continue to work as designed and are gathering excellent data. This report contains a system, subsystem, and instrument summary of the launch and early orbit operation of all TRMM components through the first 60 days after launch and includes the performance of the ground system and the early science data.

2. System Performance

The performance of the Flight segment has either met or exceeded all design requirements, as has the ground segment. Both the Mission Operations and TSDIS have performed very well, meeting all requirements. This section highlights the performance aspects of the spacecraft subsystems and instruments.

Table 2-1 shows the TRMM Observatory performance parameter requirements as defined prior to launch and what is actually being met at 60 days after launch.

Parameters	Requirements	L + 60 days
Altitude	350 ± 1.25 km	350 ± 1.25 km
Life	3 years	3 years + 5 months
Inclination	35 ± 0.1 degrees	34.98 degrees
Eccentricity	0.00054 ± 0.0001	0.00054 ± 0.0001
3-Axis Stabilized	Nadir Pointing	Nadir Pointing
Launch Mass	3523 kg	3522.9 kg
Fuel (Hydrazine)	890.0389 kg	859.0768 kg (@ L+60)
Mission Power (Load)	1100 W	850 W (Orbital Avg)
Attitude Knowledge	0.2 degrees (3σ)	0.1 degrees
Attitude Control	0.4 degrees (3σ)	0.2 degrees
Data Capture	100% goal	99.999%
Command/Telemetry		
Frequency (fwd link)	2076.94152 MHz	2076.94254 MHz
Frequency (rtn link)	2255.5 MHz	2255.5 MHz
Data Rates (omni, rtn)	1.0, 1.5, 4.0, 8.0 kbps	1.0, 1.5, 4.0, 8.0 kbps
Data Rates (TDRS, rtn)	32/2048, 32/128 kbps	32/2048, 32/128 kbps
Data Rates (fwd)	0.5, 1.0 kbps	0.5, 1.0 kbps

Table 2-1 TRMM Performance Parameter Requirements

The following sections provide details on the performance of the operations, ground systems, and Observatory subsystems and instruments.

3 Science Overview

Science data became available from TRMM far earlier than anticipated. TMI data was immediately compared to images from the previously available SSM/I instrument showing the increased spatial resolution and no serious calibration problems. A more quantitative comparison with SSM/I data is continuing. Since the differences are smaller than the absolute accuracy of the instruments, a plan to recalibrate TMI to SSM/I is being explored. This is not a reflection on which instrument is correct, but rather a tradition in Earth Sciences to intercalibrate sensors in order to obtain a long, stable time series of data.

Data from the Precipitation radar became available on 97-342. Initial data showed very high quality vertical structure but the overall calibration was in question. Serious problems were also evident in the surface detection algorithm. With the help of the Active Calibrator in Japan, as well as known properties of surfaces, the PR was recalibrated during January and February. New calibration tables were loaded into TSDIS on March 1st and the surface detection algorithm was improved and loaded into TSDIS on March 12. Since then the PR data look absolutely spectacular. The attenuation correction algorithm developed by Toshio Iguchi of CRL seems to be working better than even Toshio envisioned this early in the mission. Image comparisons between the TRMM PR and the ground based radar in Melbourne, FL show that PR is just as good as the ground based measurements but PR has better vertical resolution and does not suffer from ground clutter and anomalous propagation problems which always plague ground based systems.

VIRS data became available on 98-022. It was immediately used to compare results from it to the TMI and PR derived monthly rainfall products. The ability to compare VIRS derived rainfall precisely to the coincident TMI and PR measurements immediately confirmed the suspicion that IR produces too much rain over land and not enough over the oceans. Previous observations always used geostationary IR so that it was never quite possible to distinguish the errors in the physics from the errors in the sampling.

LIS and CERES, although not TRMM instruments, are beginning to collaborate and contribute to the TRMM measurements. Lightning, in particular, seems very well correlated to some of the differences we are beginning to see between oceanic and continental rain systems.

The early success has already spawned a number of interesting science questions that can be addressed before having a long record of fully calibrated data:

Warm rainfall processes: Warm rain contributes an unknown amount to the global total. Is the number large or a scientific curiosity? Did IR and passive microwave turn the rainiest place in the world (Hawaii upslope) into a desert? Ratios between monthly rainfall products are beginning to shed light on this topic.

Drop size distributions: Monthly averages from different sensors agree fairly well but individual scenes of TRMM data show that poor assumptions may have been made about the sizes of raindrops in the past. This is currently being looked into. Field experiments will shed more light on this question, but this could have large implications for the entire 10 year record of past rainfall estimates as well as future estimates.

PR quality: PR sensitivity (17 dBZ) is far beyond expectation and lets us get physical insight into storm structures. Calibration is good enough that it can help with large area rainfall product for Houston as a radar intercalibrator. Can space radar help out ground problems?

Land/Ocean: Monthly maps show large differences between IR and microwave. IR is higher over land. Microwave is higher over oceans. Lightning is observed virtually every place where IR overestimates. Is this consistent with our understanding of the dynamics of precipitation?

4. Flight Operations

Flight Operations were conducted as planned during launch and the 60 days following launch. A full Flight Operations Team (FOT) of 17 people was in place for the launch and checkout of the TRMM Observatory. The FOT staffed the Mission Operations Room (MOR), Mission Analysis Room (MAR), and Special Operations and Test Area (SOTA) 24 hours a day for the first two weeks on orbit. MOC developers and Flight Dynamics Facility (FDF) personnel were assigned to the control center, and were on call for any problems that arose. Coordination with the FDF worked well after the launch slip. The FOT and FDF also worked well together in coordinating the descent maneuver schedule and stationkeeping (Delta-V) maneuver information, as discussed in Section 4.2. Coordination with the Network Control Center (NCC) and the Space Network (SN) also resulted in no major problems with TDRS scheduling or in obtaining the critical TDRS events that were needed for checkout and normal operations.

4.1 60 Day Checkout Activities

The Mission Timeline from launch through the first 60 days is shown in Figures 4.1-1 through 4.1-3. This schedule was developed by the FOT, with inputs from the subsystem engineers, instrument engineers, and FDF. The timeline was followed according to plan with some adjustments made.

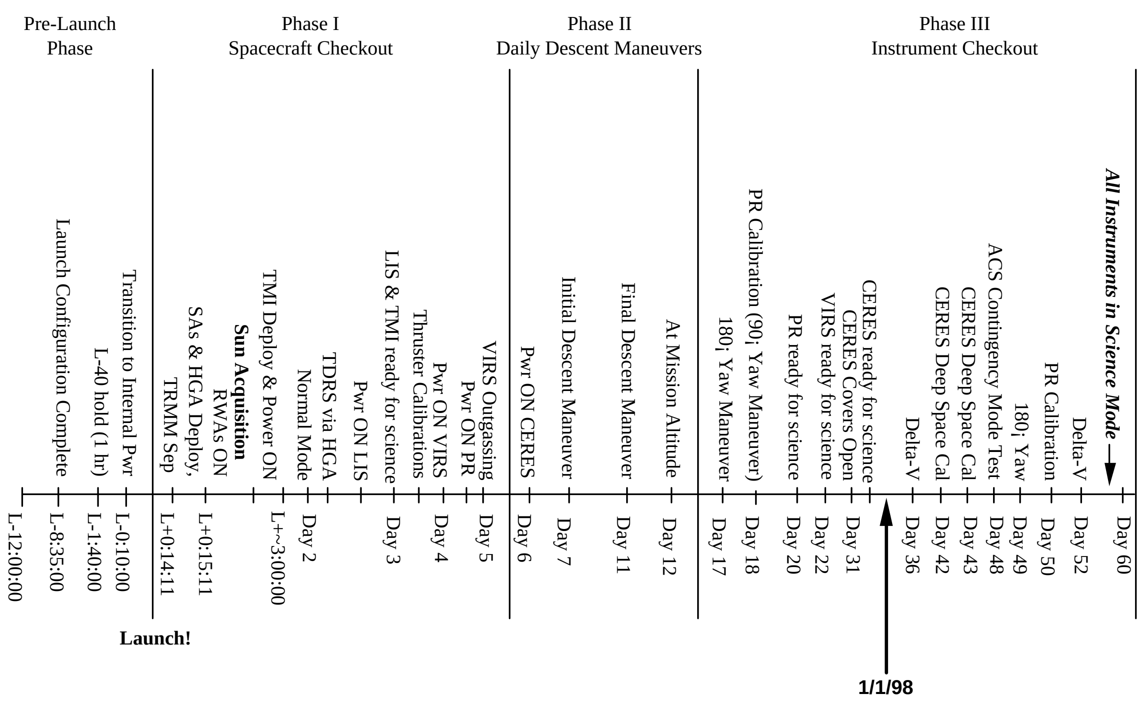


Figure 4.1-1 60 Day Checkout Activities

Launch occurred on 97-331-21:27. Fairing separation and spacecraft separation occurred 3 minutes 37 seconds and 4 minutes 11 seconds after launch, respectively. The Solar Arrays and High Gain Antenna were successfully deployed by an automatic sequencer which began executing after confirmation of spacecraft separation. Sun Acquisition was accomplished within 10 minutes after separation, due to low tip-off rates. The TMI bucket and antenna were successfully deployed approximately 3 hours after launch. Bucket deployement was verified almost immediately, while antenna deployement was not verified until power had been provided to TMI, initiating the output of TMI data. Day 2 consisted of testing the ACE Safehold mode and the Contingency “mode”. TRMM performed nominally in each of these tests for 1 and 4 orbits, respectively. Also on the day after launch, the LIS instrument was powered on, SPSDU B and PSIB B were powered off, and the RCS pressure regulator pyro was fired. Again, all events were nominal. Transition to ACS Normal mode occurred near the end of the second day in orbit. The next 3 days of operations consisted of initialization of HGA operations, thruster calibrations, and powering on the TMI, VIRS, and PR instruments.

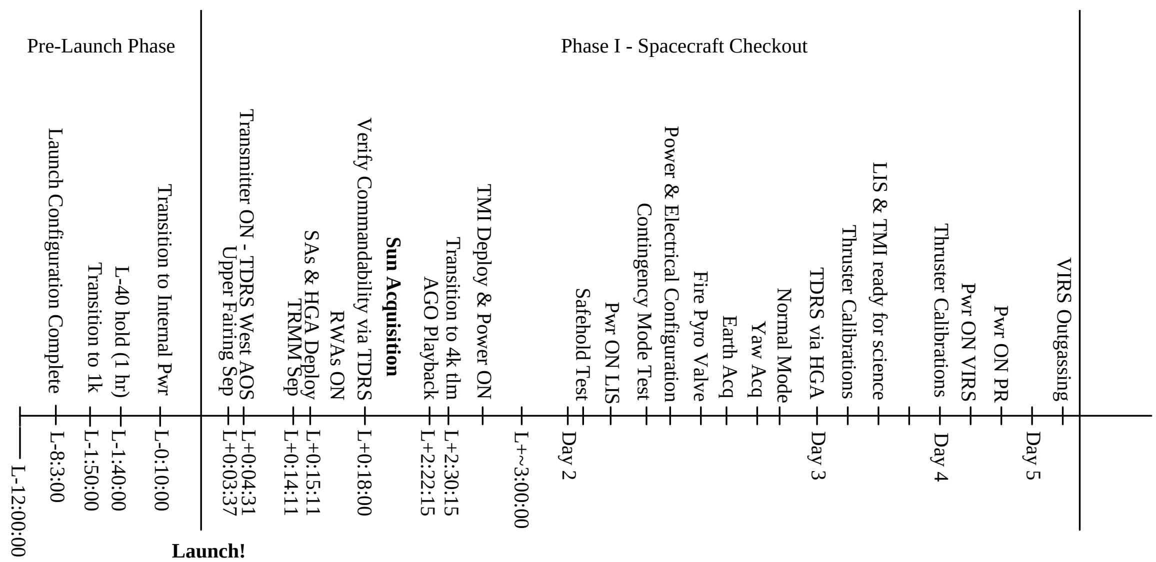


Figure 4.1-2 L - 12 hours to L + 5 days

Six days after launch, the CERES instrument was powered on, and CERES checkout began. During the following five days, eight descent maneuvers were performed to place TRMM at the mission altitude of 350 km. Once mission altitude was reached, spacecraft and instrument activities continued, including a 180° yaw maneuver and a 90° yaw maneuver for PR calibration. VIRS outgassing was performed over a period of fourteen consecutive days. CERES main covers were opened on 97-361, at which time internal and solar calibrations, which had been performed with the covers closed, continued. The first Delta-V maneuvers were performed on 97-353 and 98-001. Six non-contiguous orbits in the Inertial hold configuration were performed for CERES Deep Space Calibrations on 98-007 and 98-008.

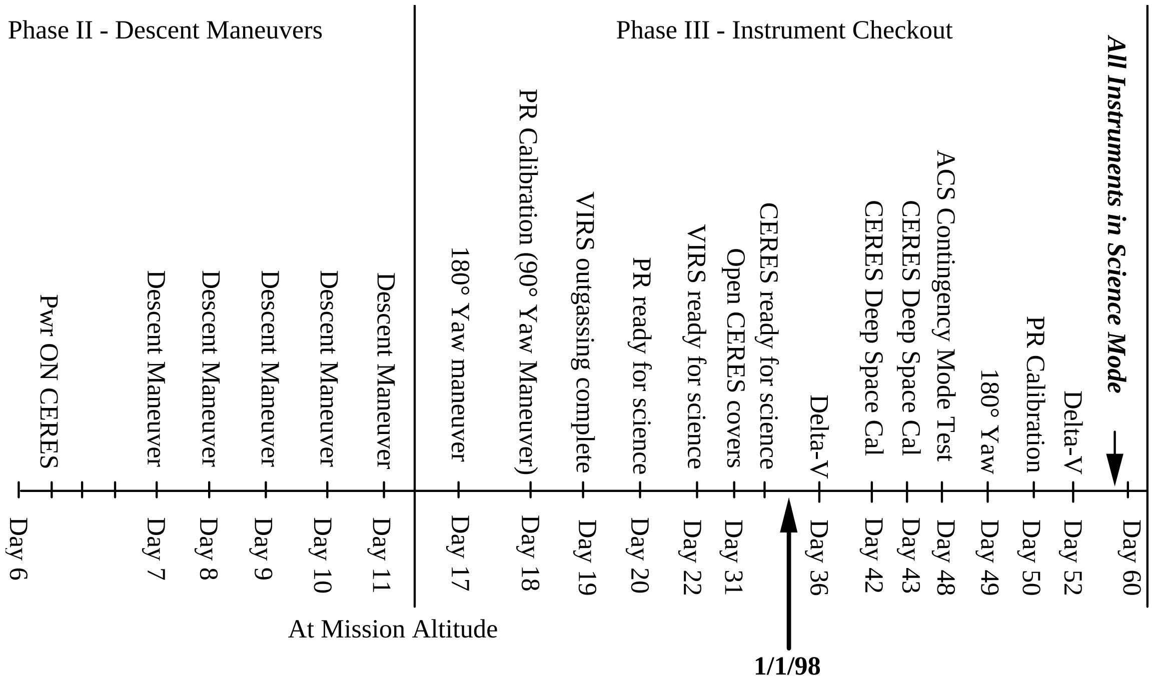


Figure 4.1-3 L + 6 days to L + 60 days

4.2 TRMM Mission Operations Center Operations

The TRMM control center has been staffed 24 hours a day, seven days a week since launch. TDRS events, approximately one per orbit, are taken by two real-time console analysts who are responsible for the immediate health and safety of the Observatory, in addition to capturing and accounting for all the science and housekeeping data on the ground. During each 20 minute TDRS contact, a series of approved STOL procedures are used to perform the normal housekeeping duties. In addition, limit checking is performed each event to ensure that all spacecraft parameters are operating nominally.

Approximately 17-20 TDRS events have been scheduled per day. The majority of events were scheduled at the nominal coherent 32/2048 kbps data rate for routine operations. In addition, one event was scheduled per day which included a coherency switch in order to obtain at least 5 minutes of one-way tracking data and frequency measurements. During these events, nominal playback and data accounting were performed during the first half of the event. Halfway through the event, a coherency switch was performed, with the Q-channel data rate reduced to 128 kbps. Also, one non-coherent event (1/4 kbps) was scheduled per week using the omni antennas on transponder 2 in order to obtain frequency measurements from that transponder.

Data capture since launch is at 99.999%. The recorders overflowed on 97- 344 and 98-026 causing a minimal loss of TMI and VIRS data. (Anomaly #34 and Event # 9). Recorded science and housekeeping data is played back each high rate TDRS event, initiated by stored commands. The console analysts account for any missing or out of sequence frames in the playback, retransmit the necessary frames, and when all are accounted for on the ground, release the dataset for all virtual recorders.

The MOC software incorrectly shows data gaps for out of sequence frames, requiring retransmits of data every event. Pacor II has only seen real data gaps that required a retransmission during one event since launch. This is an outstanding Discrepancy Report (DR) on the MOC system, since it causes the console analyst to perform unnecessary commanding to the spacecraft for retransmission of data that has already been accounted for by Pacor II. The effect of this is that operations efficiency is decreased, however, it poses no threat to the spacecraft.

The first stored command load was uplinked to the spacecraft on 97-332 and included AOS and LOS commands for TDRS and DSN events. Each day since then, the stored command buffer has been loaded once per day. Each load consisted of commands for the next 24-hour period, starting at the beginning of the next GMT day. The stored command load nominally contains commands to start specific RTSs for all of the AOS and LOS TDRS events. In addition, daily CERES commanding for Crosstrack and Biaxial mode operations are included in the loads, as are commands to put PR into the Standby mode while TRMM is over a certain region of Australia. Additional commands are added to the stored command load as requests are received from the different instrument personnel and facilities. At the end of each load is a safing sequence which configures the system if the next day’s load is not uplinked.

A TRMM Extended Precision Vector (EPV) is loaded to the spacecraft each day to begin propagating at 20:00. The initial EPV was loaded just prior to exiting Sun Acquisition mode on 97-332. Also, prior to using the HGA with TDRS, TDRS EPVs were loaded and are uplinked nominally once per month.

No regular table loads have been necessary to date. Table loads from launch up to the present time are described in the appropriate subsystem sections. In addition, Appendix D documents each table load since launch and the purpose of the load.

The FOT documents all available information about events, anomalies, and routine operations. Each week, information is provided to various TRMM personnel in a Weekly report. Anomaly and Event reports are used to document spacecraft and ground system anomalies, respectively.

4.2.1 Offline Analysis

As the TRMM mission has progressed into normal operations and more long-term trending has been required, the GTAS system has proven to be reliable despite problems during the first few days and weeks of checkout operations. The GTAS system stores hourly and daily statistics which have been quite useful in understanding seasonal and solar beta angle variations and their effects on the various spacecraft components. Although GTAS is designed mostly for long term analysis, the system was still able to produce daily plots for the various system engineers, although one recurring software glitch in ingesting the Level-0 data to the optical disks produced regular delays over a period of two weeks.

The most useful aspect of the trending system during the 60 day checkout period was the ability to produce ASCII reports from binary subset data. Accounts were set up with most subsystem engineers on their personal computers, and these ASCII reports, sometimes 50 MB in size, were FTPd to them on a regular basis for analysis with their software of choice, such as Excel, Kaleidagraph, and Matlab. Trending with Macintosh applications and the GTAS generated reports is used extensively in analysis by the FOT system engineers. In addition, the binary files themselves were often sent to clients on a daily basis, particularly FDF, for analysis, ground reference validation, and sensor calibrations. Most of the anomaly reports which were closed during TRMM’s checkout period were done so with verification from the trending system. Although plot or data delays were the biggest complaint generated during the checkout period, the trending system was considered a success overall, especially for the tedious reproduction of the large amounts of housekeeping data that was often required by the subsystem engineers.

4.2.2 NCC/ TDRS Scheduling

The Network Communications Center (NCC) provides scheduling and real-time support of the Spaceflight Tracking and Data Network (STDN). Scheduling of TDRS time with the NCC has generally been good. During the week of launch, there were problems scheduling critical supports because the Space Shuttle was in orbit. With the launch delay, the scheduling of events was made even more difficult, but the NCC was able to provide the minimum of required supports in only a few hours time. In addition, the NCC was very cooperative in providing TRMM with the necessary TDRS coverage for the many descent burns and initial checkout activities that needed full TDRS coverage and were rescheduled due to the launch slip.

The bandwidth limitation of the Multiplexer/Demultiplexer (MDM) at WSC has been a factor for TRMM. There have been a few times that TDRS time has been available, but because of TRMM’s high data rate, it was rejected by the NCC.

The availability of TDRS-171 (TDRS-7) has been extremely beneficial for TRMM. The ability to use TDRS-171 began on 98-022. TRMM now regularly schedules TDRS-171 which makes data storage operations and the FDF requirement for alternating TDRSs easier to accomplish. Currently there are four TDRSs that TRMM schedules routinely: TDE, TDW, TDS, and TD7 (171).

4.3 FOT/FDF Interaction

Thanks to the series of meetings held before launch designed to finalize the FOT/FDF Operations Agreement, most of the details outlining the information exchange between the FOT and FDF were established and in place prior to launch. One of the more important accomplishments was the finalizing of the subset files which would ultimately include all of the ACS mnemonics which FDF would need to analyze TRMM's performance during its first 60 days on-orbit. This information was then used to produce calibrated data for the Earth Sensor Assembly (ESA), the Three Axis Magnetometers (TAMs), and the Inertial Reference Unit (IRU) gyros. The content and delivery schedule of the products which FDF regularly sends to the FOT in order to generate EPVs, daily loads, and maneuver loads were also developed prior to launch. Similarly, the products which the FOT sends to FDF before and after Delta-V maneuvers were also outlined in advance. This interaction has worked quite well over the course of the 13 orbit adjust and calibration burns which took place during the first 60 days on orbit.

4.3.1 Products

During every real-time pass, the FOT collected important ACS information in a subset file called TATT, which was then transferred via FTP to FDF after every TDRS event. In addition, a full 24 hour dataset which contained merged real-time and recorder playback ACS telemetry was delivered nightly to FDF for analysis. This large amount of data was instrumental in producing the sensor calibrations and ACS performance evaluations which FDF produced for the FOT. The daily and weekly files which FDF delivered to the MOC, including PSAT, SBA, EPV and UAV files, were the key to TRMM's success in maintaining a daily EPV uplink schedule, as well as producing the daily loads and maneuver loads with an adequate amount of real-time coverage support. The FORMATS software which is installed in the MOC is the key to formatting and moving the large number of FDF files which are delivered on a daily basis.

FDF also delivered software products which were used regularly during the TRMM checkout period, primarily GSOC, RTADS, and HUD. The GSOC utility was and continues to be regularly used for predicting solar and lunar interference times for the sensors and instruments. The RTADS and HUD utilities were used by FDF personnel for ground validation of ACS on-orbit parameters during the critical first week of TRMM operations. The exchange of products between the MOC and FDF was therefore one of the major keys to TRMM's success during early orbit operations, and should contribute to four solid years of valuable science gathering.

4.3.2 Maneuvers

During the first 60 days, 13 Delta-V maneuvers and calibration burns were performed. Two days prior to each burn, the FOT sent FDF average telemetry values for fuel and pressurization tank pressures and temperatures which were then used by FDF to prepare the maneuver planning file. One day prior to each maneuver, FDF sent the MOC the maneuver command file, which was then reviewed, approved, and used to generate the load for the maneuver. After each maneuver was completed, the FOT sent FDF data used for calibrating the maneuver and generating the post maneuver report and fuel budget analysis.This data included thruster ON times, as well as tank pressures and temperatures. This information exchange has allowed the FDF and the FOT to conduct maneuver operations quite well, which will become even more important towards mission end of life when maneuvers will be performed much more frequently.

There were a few minor glitches in the first week or two after launch, but there have been no recurrences since. For example, following the maneuver on 97-339, White Sands did not receive an updated ephemeris (Anomaly #30), and as a result, the MOC was not able to acquire telemetry via TDRS for two events until the updated ephemeris was delivered to White Sands. In contrast, the LBS maneuver which was conducted on 98-024 was aborted due to a tight limit on the initial pitch torque, and the FOT immediately notified FDF of the situation. The cooperation was instrumental in getting the spacecraft ready for a new burn on the following day, including the generation of an updated EPV for uplink. Similarly, the products used by the FOT for planning the 180° and 90° yaw maneuvers, as well as the series of six inertially fixed CERES calibration maneuvers, all worked quite well. As with all operations, the goal now is to ensure that the procedures in place become even more streamlined, and as immune to personnel changes as possible.

5. Ground System Overview

This section is an overview of the software and hardware aspects of the Mission Operations Center (MOC), as well as, the interfaces with the external data distribution centers, such as Sensor Data Processing Facility (SDPF), TRMM Science Data and Information System (TSDIS), and the Distributed Active Archive Center (DAAC).

5.1 Ground System Operations

TRMM has been operated since launch by the Flight Operations Team (FOT) in the Mission Operations Center (MOC) at Goddard Space Flight Center (GSFC). TRMM ground system operations have performed satisfactorily.

5.1.1 MOC Hardware

The MOC hardware overall has operated acceptably. All three MOC strings and all three SOTA strings were operational for launch. The system strings and front ends have had minimal down-time during launch and checkout. Response time by system administrators and hardware maintenance has been sufficient to keep the system running smoothly.

However, the prime and off-line string's file storage system, the RAID, and the system fileserver have been constantly vulnerable. Platter 2-A has been the main component of the RAID that has failed, sometimes for weeks at a time. When the RAIDs Platter 2-A was successfully built, it was operational only for a few days. System administrators have been working with the manufacturer to correct and replace suspected bad hardware. A possible resolution to replace the RAID with a fixed hard disk system is being considered. In addition, there have been occurrences of hanging and crashes of the server workstation. The server "hangs" have been common, but only impact operations for approximately 10 minutes until the "hang" clears itself. Server workstation crashes are rare, but impact all operations until the server system has been brought down and rebooted. This impact consists of a necessary failover to the redundant string and fileserver.

The Local TPOCC Switch (LTS) and NASCOM lines have worked very well. Line and port problems are rare. TR-1 (the I channel and commanding line) was lost for an event due to NASCOM using it for testing on 97-028 (Event #11). Problems with the NCC line on Port-3 of the LTS (port for the NCC messages for the prime string) required a switch to the back-up Port-14. It was determined that Port-3 is fine, but the backplane connected to the port was bad. A final decision was made to use Port-14 as the permanent NCC port for the prime string.

Overall, services that have been provided by White Sands Complex (WSC) and the Network Control Center (NCC) have been excellent. There have been a few ground system problems that are logged in Event reports (see Appendix B). These events are generally infrequent and have not greatly impacted operations or caused any data loss.

The Voice Distribution System (VDS) has performed efficiently. There were numerous CCL and SCAMA lines configured for launch and early orbit checkout, including five lines to Japan. The combination of handsets and headsets allowed sufficient flexibility during busy launch operations and noisy voice traffic. Before launch, the addition of several DKS phones provided the remaining workstations with effective communications. The communications have generally been excellent. SCAMA #239 was changed from an isolated loop to a TDRSS operations multi-user loop on 98-013. A few SCAMAs and CCLs have occasionally had some scratching noise. The outside line 301-286-0198 has been out of service since 98-019.

5.1.2 MOC Software

The MOC has three major areas of software. The real-time software used to command and monitor the spacecraft; the Mission Planning software used to plan maneuvers and generate daily and Delta-V loads; and the GTAS software used in off-line trending of data received from SDPF level-0 files, real-time history files, and real-time subset files.

The real-time system has been quite reliable. A few minor problems (Anomaly #9, 19, 22) still exist that will be fixed and delivered in the next two releases of software (post-launch Releases 7.0 and 8.0). Virtual Recorder accountability and clock correlation have been very good, although, there are currently issues with clock correlation using the Range Data Delay (RDD) method at the 4 kbps data rate. In addition, clock correlation with the User Spacecraft Clock Calibration System (USCCS) method is unsuccessful for one event following a coherency switch. Clock correlation using the USCCS and RDD methods have been used successfully with the 32 kbps/2 Mbps and 1/1kbps rates. The RDD method was successfully used to perform the initial adjustment of the clock on launch day, since then it has only been used for testing, due to the constraint that the system must be restarted after the event.

Database Version 9.1 was made operational 98-026. Some telemetry limits have been reworked to reflect current operations. The database incorporated all of the necessary modifications that were discovered since launch, as well as new pseudo telemetry points. Limit checking by the MOC software has been excellent.

The mission planning system has been relatively stable. S/C ATS loads and ACS EPV loads have been generated for each day and ACS Delta-V loads as needed. There have been minor problems with the accuracy of Integrated Print reports and the MOPSS planning system. CERES modeling has successfully generated the solar avoidance commanding for CERES using the Guide Star Prediction and Occultation (GSOC) utility provided by FDF. Several Macros (sequence of stored commands) have been generated and used for Yaw maneuvers, CERES Deep Space Calibrations, PR, CERES, and VIRS instruments during checkout and normal operations.

The off-line trending software Generic Trending Analysis System (GTAS) has not had any major problems. GTAS was used extensively for launch and continues to be used for anomaly investigations. There was a software glitch that caused delays to ingesting and product generation for the first two weeks after launch. The software problem affected the ingestion of files to the optical disk residing in the Juke box. The GTAS system has generated many orbital plots, statistical reports, and ascii reports, despite the initial delays.

5.1.3 SDPF/FOT Interface

Operations between the SDPF and FOT have worked very well. During the launch phase and first couple of days of checkout, Data Distribution Facility (DDF) was delivering Level-0 files electronically to the MOC within a couple hours after the day change. This enabled the FOT to generate numerous plots and ASCII reports using GTAS during the night shift for the following morning's meeting. Since then, SDPF has consistently provided the Level-0 files within the required 24 hours of data capture. The only difficulty has been in recovering Level-0 data off of the delivered CDs, but this is a low impact problem since the files can be resent electronically by SDPF upon request.

5.2 TSDIS Operations

TSDIS is comprised of two segments: the Science Operations Control Center (SOCC) and the Science Data Operations Center (SDOC). The following sections describe the operations that occurred during the first 60 days of TRMM's mission, which include instrument operations and data processing.

5.2.1 Science Operations

The SOCC operations have gone well. TSDIS receives mission planning products and real-time schedules from the MOC on a regular basis. These planning products are used in geolocation analysis with science data, as well as, predictions for mission planning. The TDRS event schedule is used to plan real-time instrument monitoring via a remote login to the MOC.

The TSDIS transmits command requests to the MOC for PR, VIRS, and TMI via e-mail. During the initial 60 days, there have been 10 command requests transferred to the MOC, five PR and five VIRS requests.

5.2.2 Satellite Data Processing

TSDIS began processing data products from the satellite instruments the day after the first instrument was turned on. This early data helped the instrument scientists ensure that the instruments were producing data as expected. This early mission data is not considered operational data.

While 31 TMI 1A and 1B products were produced in November already, true standard processing began in December. TMI data products were the most mature and TSDIS was able to produce them for almost every day within December. VIRS and PR were activated later in the month. For most of early December, PR was involved with its calibration process.

Table 5.2-1 below provides the number of granules that TSDIS produced and sent to the GSFC DAAC for archive. A granule for level 1 and level 2 is a single orbit. Granule for Level 3 is 30 days.

Data Type	December	January	February
VIRS 1A01	488	489	441
TMI 1A11	488	489	441
PR 1A21	378	489	441
VIRS 1B01	457	489	441
TMI 1B11	488	489	441
PR 1B21	378	489	441
PR 1C21	378	489	441
TMI 2A12	378	489	441
PR 2A21	173	489	441
PR 2A23	173	489	441
PR 2A25	173	489	441
Combined 2B31	173	489	441
TMI 3A11	1	1	1
PR 3A25	1	1	1
PR 3A26	1	1	1
Combined 3B31	0	0	1
Other 3A-42	0	0	0
Other 3A-43	0	0	0

Table 5.2-1 Granules Produced by TSDIS

3A-42 and 3A-43 are TRMM and other satellite products; these were run each day. This daily processing produces an intermediate product that is then run approximately once a quarter when other needed data is received from NOAA through the GSFC DAAC. This final processing produces the actual output product.

5.2.3 Ground Validation Data Processing

In addition, to the satellite products TSDIS also ingests and produces radar data from four major ground validation sites. It ingests 1B51 and the quality controlled 1C51 product from the JCET group which carries out the rather detailed and manually intensive quality control. These products are then forwarded to the GSFC DAAC for archive and distribution.

TSDIS uses the 1C51 data product to produce the level 2 and level 3 ground validation products. A 1C51 granule is an hourly product. The Level 2 GV products are also hourly. Level 3 products are either 5 day (3A-53) or 30 day products (3A-54 and 3A-55).

GV processing did not start at the same time as satellite processing. This was caused by problems with the algorithm delivery as well as differences between the manner in which some algorithms processed and the way that the automated scheduling in TSDIS works.

Table 5.2-2 below shows the GV products produced for each for the months listed for all four of the primary sites.

Data Type	December	January	February
1B51	2367	2233	708
1C51	2971	2269	696
2A52	4	2	1
2A53	2970	2232	575
2A54	2969	2247	576
2A55	2971	2247	576
3A53	6	0	0
3A54	0	0	0
3A55	0	0	0

Table 5.2-2 Products Produced

5.2.4 Product Ordering

TSDIS delivers orders to users in three different manners.

1) If the user orders a specific product through the RST and that product is still within TSDIS, then TSDIS itself will fill the order either through network or tape.

2) If the user orders a specific product through the RST and that product is no longer within TSDIS, then TSDIS sends the order directly to the GSFC DAAC for filling under the original agreement with the EOSDIS project.

3) If the user has established a standing order that requests that data be sent to the user anytime it is produced, TSDIS services the order directly if it is a network request. If it is a tape request then the GSFC DAAC fills the order on behalf of TSDIS. This latter agreement was funded by TRMM and was never an EOSDIS requirement on the DAAC.

Table 5.2-3 below indicates how many times a granule was requested in the months listed. In addition the table provides information as to whether TSDIS serviced the granule directly, sent it to the DAAC under the EOSDIS agreement or the GSFC DAAC serviced a tape standing order on behalf of TSDIS.

Data Type	Dec	Dec	Dec	Jan	Jan	Jan	Feb	Feb	Feb
by	TSDIS	EOSDIS	DAAC	TSDIS	EOSDIS	DAAC	TSDIS	EOSDIS	DAAC
1A01	2	0	110	8	80	536	35	0	158
1A11	99	0	0	0	193	0	0	0	0
1B01	57	0	110	82	1805	963	122	31	600
1B11	644	0	520	1310	1564	1499	891	30	1326
1B21	44	0	220	23	67	1119	4	0	884
1C21	45	0	109	36	1580	995	49	0	1326
2A12	20	0	0	42	99	0	41	0	0
2A21	0	0	55	458	215	699	426	15	884
2A23	0	0	95	0	420	632	15	0	884
2A25	32	0	53	2	353	593	0	0	457
2B31	32	0	47	1	91	577	0	0	479
3A11	0	0	0	0	3	0	0	0	0
3A25	0	0	0	4	11	1	3	0	1
3A26	0	0	0	3	9	0	3	0	0
3B31	0	0	0	0	0	0	4	0	0

Table 5.2-3 Granule Requests

5.3 DAAC Operations

The Distributed Active Archive Centers discussed below reside at Goddard Space Flight Center and at Langley Research Center. These centers are ultimately responsible for TRMM science data, including processing, long term storage, and distribution of the data. All DAAC operations within the first 60 days went well.

5.3.1 Goddard DAAC

The GSFC Distributed Active Archive Center's TRMM Support System (TSS) was fully ready for launch on 97-331, about one year after development commenced as a contingency for the EOSDIS Core System. The first data from TSDIS (Ephemeris, Housekeeping and Microwave Imager L1A) were received on 97-346. Ground Validation data began arriving a few days later, on 97-351. Precipitation Radar and Visible Infrared Scanner data began arriving on 98-358. Finally, the Level 3 data began arriving on 98-002. Ingest and archive of all data products proceeded smoothly for the first 60 days, with few problems compared to the initial arrival of data streams from previous projects: this was a testimony to the fidelity of the TSDIS-TSS interface.

Distribution of data from the TSS began with automated (subscription) distribution of ancillary data to TSDIS on 97-357. Requests received from TSDIS on behalf of TRMM Science users through the Data Request protocol were first processed on 97-363. TSDIS requests for data via the same mechanism started 98-017. Automated distribution of VIRS Level 1A to the Langley TRMM Information System (LaTIS) began on 98-005. Shipment of monthly standing orders on 8mm tape to NASDA began on 98-015 (roughly one month after first data arrival). Shipment of weekly standing orders to TRMM Science Users commenced 98-020. Thus, all distinct request mechanisms were exercised during the first 60 days. Only one significant problem (an omission of some data in the NASDA monthly standing orders) was encountered; that problem has since been remedied and the missing data shipped to NASDA.

The Distributed Active Archive Center also promoted the TRMM data at two major scientific meetings during the first 60 days. DAAC scientists presented a poster at the American Geophysical Union meeting in December, 1997, and distributed leaflets with the First Images of TRMM, provided by Dr. Kummerow, at the American Meteorological Society meeting in January, 1998.

5.3.2 Langley DAAC

Starting with the 97-336 activation of the CERES instrument on TRMM, the Langley DAAC began processing the launch version of CERES data. The first Quick-Look data file arrived and was made available to the CERES team that evening and by the evening of 97-337, the first daily run of the CERES instrument subsystem had been completed using Level 0 CERES data and TRMM orbit and attitude data. Daily instrument processing continued in support of CERES instrument checkout until the opening of the CERES contamination covers on 97-361. Starting with the 97-361 data, the DAAC performed daily processing of the CERES instrument and ERBE-like subsystems to support the initial science check-out period. In concert with the CERES team, a strategy of producing the daily instrument and ERBE-like products within 36 hours of the end of the Level 0 time period was adopted. Ingest of Level 0, orbit, and attitude data and processing of the instrument and ERBE-like subsystems proceeded very successfully with only a few operational problems related to things such as network difficulties, processing of attitude and orbit data, and manual operation of the processing system.

The Launch version processing during the first 60 days of operations has involved the production of about 120 Gb of data. Principal products included the daily BDS (Bidirectional Scan) and IES (Instrument Earth Scans) from the instrument subsystem and the daily ES-8 (ERBE-like Monthly Regional Averages) and monthly ES-9 (ERBE-like Monthly Regional Averages), ES-4 (ERBE-like Monthly Geographical Averages), and ES-4G (ERBE-like Monthly Gridded Averages) from the ERBE-like subsystem. The data have been used by the CERES team in evaluating initial instrument operations and preparing for CERES Science Team assessment of products.

During this period, the DAAC has also ingested from various data providers a number of ancillary products required for subsequent CERES processing subsystems. These included data from the Data Assimilation Office, the GHRC, the Goddard DAAC, and the NSIDC.

6. Subsystem Operations

This section outlines the checkout activities performed with the various spacecraft subsystems after launch and the performance of those subsystems during the first sixty days of the mission. Many activities have happened that involve multiple systems, for which the relevant information will be presented in each system individually.

6.1 Attitude Control Subsystem (ACS)

The TRMM ACS subsystem has performed well and has met or exceeded all the expectations for normal mission mode as well as during maneuvers. Descent maneuvers were used to place the TRMM Observatory in its correct mission orbit and stationkeeping maneuvers were used to maintain mission altitude. Yaw maneuvers were used to maintain a cool +Y side of the spacecraft, as well as for VIRS protection and PR calibration. Inertial hold maneuvers were used to calibrate the CERES instrument and ACS Inertial Reference Unit (IRU) gyros. In addition, tests were conducted to verify the capabilities of both Safe-Hold operations and non-ESA based Contingency Mode operations. Concerns regarding the capability of meeting pointing requirements should the ESA performance significantly degrade were alleviated. The TRMM ACS is currently meeting its specification for pointing the TRMM Observatory for nominal science gathering operations.

6.1.1 Launch through Sun Acquisition

Upon separation from the H-II, the RWAs were autonomously powered on by the SPSDU sequencer and the Observatory transitioned nominally from Standby Mode to Sun Acquisition Mode. When the Observatory entered Sun Acquisition Mode the roll, pitch, and yaw errors were -8°, -26°, and -25°, respectively. The total system momentum was 15 Nms. The H-II tip-off rates, as monitored by the gyros, were -0.02, -0.13, and 0.04 °/second for roll, pitch, and yaw, respectively. These rates were well below the H-II specified rates (less than 1-sigma), and as a result the four RWAs were able to achieve Sun Acquisition in less than 10 minutes.

On 97-331-22:27 the on-board Fault Detection and Correction (FDC) test #16 marked the TAM A as static and autonomously switched to TAM B (Anomaly #2). This occurred because the on-orbit noise on both TAMs was lower than the static threshold (3.125 E-2 μT) that is used to decide if the TAM data is updating correctly. This static threshold in Table #57 was lowered to 2.0 E-2 μT on 97-335 and TAM A is again being used. There was never a problem with TAM operation, the TAM data was simply less noisy than was expected based on pre-launch test results and predictions.

6.1.2 ACS Safe-Hold Test

TRMM conducted a planned test of the ACS safe-hold mode from 97-332-13:17 to 97-332-14:48. The Observatory entered safe-hold when the FOT started the safe-hold stored command RTS. Although the ACE control algorithm is always running in the background, it is only during this mode that the Observatory is held in an inertially fixed, sun-pointing attitude and is actually controlled by the ACE. The ACE relies on the Coarse Sun Sensors (CSSs) and gyro analog rates to maintain the stable sun-pointing attitude and a Three Axis Magnetometer (TAM) and Magnetic Torquer Bars (MTBs) to maintain reduced levels of system momentum. Various attitude and power parameters were closely monitored during the test to ensure the ACE was accurately controlling the spacecraft, and all safe-hold operations, including the return to ACS control in Sun Acquisition were nominal.

6.1.3 ACS Sun Acquisition Mode Contingency Mode Test

During Sun Acquisition the ACS Contingency Mode method for attitude determination was tested. In the event of Earth Sensor degradation, the ACS uses the Digital Sun Sensor (DSS) and TAM data to estimate Observatory attitude and gyro biases via a Kalman filter algorithm. In Sun Acquisition, TRMM maintains an inertially fixed, sun-pointing attitude using the CSSs and gyros. The Kalman filter output is available, but it is not used for pointing the Observatory. Thus the performance of the Kalman filter could be tested without affecting performance.

The test began at orbit noon on 97-332-16:21. It was tested using DSS and TAM data, but only TAM data during eclipse. The performance was within specification for all cases. However, when the Kalman filter was reinitialized in eclipse, it did not accept the DSS data when it became available again. The filter algorithm was overemphasizing the TAM measurements, and subsequently rejecting the DSS data as inaccurate. The ACS used the data collected from the test to re-tune the Kalman filter and adjust the TAM and DSS weightings accordingly for the next test which would occur during Mission Mode. On 97-332-20:30 TRMM exited Contingency Mode and returned to Sun Acquisition Mode.

6.1.4 Earth Acquisition and Yaw Acquisition Modes

On 97-332-21:03 the first Earth Acquisition was performed, once the target orientation was set to +X forward. The ESA changed from coarse processing to fine processing (roll and pitch position error angles less than .0174 radians) on 97-332-21:14, and on 97-332-21:16 the Observatory entered Yaw Acquisition Mode. On 97-332-21:25 the Observatory entered Mission Mode for the first time. There were no problems in Earth Acquisition mode or Yaw Acquisition mode or in the transitions between modes.

6.1.5 Mission Mode

Mission Mode performance is currently nominal and well within pointing requirements.

Upon first entering Mission Mode, yaw updates of approximately +0.3° from DSS A and -0.3° from DSS B were observed (Anomaly #25). Analysis of the data revealed that this occurred because the DSS heads had been mounted slightly non-orthogonal to each other. The forward DSS A heads were non-orthogonal by 0.08 degrees, and the aft DSS B heads were non-orthogonal by 0.3 degrees. A software patch could be written to account for non-orthogonal DSS heads. However, since the DSS A was only slightly non-orthogonal, it was decided to have FDF calibrate DSS B and the ESA to DSS A.

On 97-346-14:33 a new FDF-supplied alignment matrix (Table #65) was loaded for DSS-B and on 346-19:26 new FDF-supplied ESA penetration biases (Table #59) were loaded. Yaw updates improved to ±0.15° worst-case.

Yaw updates were also improved by lowering one of the gains (k-yaw) with a table load (Table #82) on 97-346-22:42 which reduced overcorrecting of the gyro bias. Tables #64 and #65 were scheduled to be modified again to further improve the yaw update magnitudes and symmetry on 98-050, and the results will be discussed in the 6 month report once long term analysis is gathered.

While in mission mode, the solar arrays track the sun during daylight but are feathered during eclipse to minimize drag. A pre-dawn criteria is set by the ACS Flight Software which allows the solar arrays to be slewed to the sun position before exiting eclipse. In Mission Mode it was noticed that the arrays sometimes did not reach the sun tracking position until more than one minute after sunrise (Anomaly #20). Since power generation is adequate, no change has been made. If power generation becomes an issue, this condition can easily be changed by updating the table which determines the amount of time spent slewing in daylight at each beta angle. It is likely that a table load will be written which will change the timing of the feathering to reduce drag and further extend mission life. The results of meetings and analysis on this subject will be discussed in the 6 month report.

Review of the Sun Acquisition Contingency Mode results revealed that the onboard magnetic field model was using inconsistent epoch time and coefficients. With the epoch for the magnetic field model hard-coded in the software, the immediate solution was to upload older, matching coefficients. A code change is being developed to update this model, and there is no impact on Mission Mode operations.

Based on data which FDF was receiving from MOC telemetry, the primary Z axis gyro scale factor was updated within Table #55 on 97-348-15:59 with the new calibrated value.

When the solar beta angle is between ± 33° and 55°, occasional Earth Sensor Assembly (ESA) interference occurs, and attitude determination is conducted using three or even two sensor heads, instead of four. On occasion, the ESA Offset Radiation Source (ORS) Voltage levels significantly increase, and ESA telemetry shows an OVER_RANGE condition (Anomaly #42). Also, during the transition back to four quadrant control, there is a sudden large position error spike which in turn causes the arrays to be commanded to gimbal in order to compensate. On 97-362-18:45 the array commanded velocity spiked to 30.048 pulses per second (pps), and the commanded gimbal position actually oscillated for a few control cycles (see Figure 6.1-1). This in turn introduced a spacecraft rate which exceeded the gyro X-axis telemetry threshold, thereby tripping FDC test #0 (Anomaly #45) which resulted in a switch to the redundant gyro. This occurred during a peak solar beta angle period of -58 degrees. ACS engineers decided to widen the threshold for this criteria from 5 to 10 consecutive samples required before limit violation (Table #53) on 97-364. It was later decided to modify Table #83 and disable filtering of the ESA S-counts, since the resulting increase in telemetry noise levels would be minimal. This change would decrease the large spikes in position error resulting from the two or three head to four head ESA control transition. These results will be discussed further in the six month report as additional data is collected.

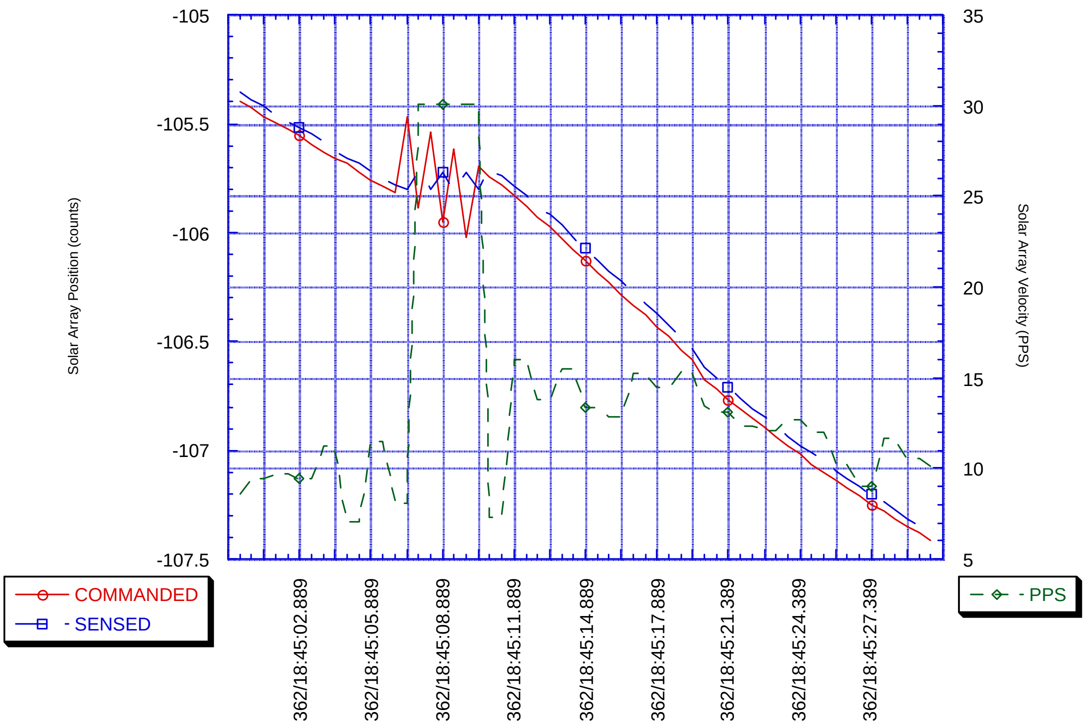


Figure 6.1-1 Effects of ESA Sensor Head Transition (Anomaly #45)

6.1.6 Mission Mode Contingency Mode Test

A new Kalman Filter Parameter ACS Table #51 was loaded on 98-012 in preparation for the Contingency mode test on 98-013, based on data from the first Contingency test.

The Contingency mode test was performed on 98-013. This test was similar to that performed during Sun Acquisition, however during this test, the Kalman Filter output is actually used for attitude control. Contingency Mode was entered at 12:13:12 with the loading of ACS Tables #102, #90, #81, and #80. The test was initiated during the sunlight portion of the orbit so that DSS measurements would be readily available to the filter, allowing better convergence behavior. The Kalman filter was then re-initialized at 15:00:00, beginning the convergence process again and allowing study of how transient behavior would affect operations if the filter is ever reset. ACS returned to normal mode at 17:02:15. Part of the exit process included clearing out the filter-based gyro bias estimates, which can become inaccurate if the filter is not continuously running.

After exiting Contingency mode, the Yaw Update using DSS-A FDC test #23 tripped. The misalignments in the DSSs introduced biased estimates in the yaw gyro drift. Furthermore, large transients which occurred during the convergence process were also integrated into the estimated gyro angle. This combination accumulated to a yaw attitude greater than the 2 degree limit set in Table #82 (the tolerance between DSS and Ephemeris sun vectors) while the spacecraft was in Contingency Mode, where only an estimate of the yaw attitude is used for control. As a result, FDC action #28 marked DSS A bad when the transition was made back to Mission mode and this bias value was once again used for controlling the spacecraft. To assure that TRMM did not enter Sun Acquisition (if both DSSs are marked bad, ACS goes to Sun Acquisition via FDC test #25), DSS A was commanded back to GOOD, and ACS Table #82 was modified by widening the thresholds for yaw updates from 2° to 20° (the same value used for Delta-V maneuvers). After the next couple of yaw updates occurred, the false 2° error was eliminated, and ACS Table #82 was reloaded with its normal threshold values.

The Contingency Mode Exit procedure was modified so that in the future, if it is ever required to exit Contingency Mode, the gyro error angles will be reset to zero before exiting, to avoid the use of any false position errors which accumulate while in Contingency mode. FDF ground solutions of the Contingency data shows that pointing was within the 0.7° requirement for Contingency Mode operations, and in fact converged closer to 0.25° in only three hours of operation. The longer the filter runs, the better the attitude estimate becomes, so it is likely that the normal operations expectancy of 0.2° pointing accuracy could be approached with the Kalman filter if significant ESA performance degradation ever becomes a reality.

6.1.7 Delta-V Performance

For information on the actual thruster, tank, and line performances, as well as a table summary of the Delta-V maneuvers, see Section 6.5, RCS Subsystem. The ACS Delta-V control mode performance has functioned nominally through the Observatory evaluation period. The initial roll thruster calibrations showed that the roll thrusters have the correct polarity and that the momentum impulses were within the expected values, although there have not been any roll disturbances during any of the maneuvers so far. All of the Delta-

V maneuvers to date have demonstrated a pitch disturbance torque. As a result, the ISP -Pitch thruster has typically off-modulated 35% of the total on time of a two burn maneuver. Some -Pitch disturbance torque is expected on TRMM while flying -X forward due to the thruster positions, orientations, and spacecraft center of gravity position. In addition, when the spacecraft is +X forward and the LBS thruster set is used, -Yaw and +Pitch disturbance torques are seen, and the LBS -Yaw and +Pitch thrusters off-modulate to compensate. Typically, the LBS -Yaw thruster off-modulates 5% of the total on time, and the LBS +Pitch thruster off-modulates 21% of the total on time.

During the LBS burn on 98-024, the maneuver aborted 10 seconds into a planned 39 second burn (Anomaly #52). The LBS +Pitch off-modulation did not occur in time to compensate for the initial disturbance torque before FDC test # 93 tripped due to high pitch body momentum (30 Nms exceeded). This value was increased to 40 Nms in Table #73, and the maneuver pair was successfully conducted the following day. The next EPV uplink after the aborted maneuver failed continuity in position (Anomaly #53). As a result, Table #86 had to be loaded to first disable ephemeris continuity checking so that updated vectors could be uplinked, then reloaded with continuity enabled again once the EPV was successfully propagating. Post-maneuver analysis showed that the pitch body momentum still reached 38 Nms before off-modulation for that second burn, however, so the table was modified once more to 45 Nms prior to the next LBS maneuver. Figures 6.1-2 and 6.1-3 show a good comparison between Delta-V LBS maneuvers 12 and 13, to see how FDC test #93 tripped on the first example just before off-modulation would have lowered the pitch body momentum close to zero.

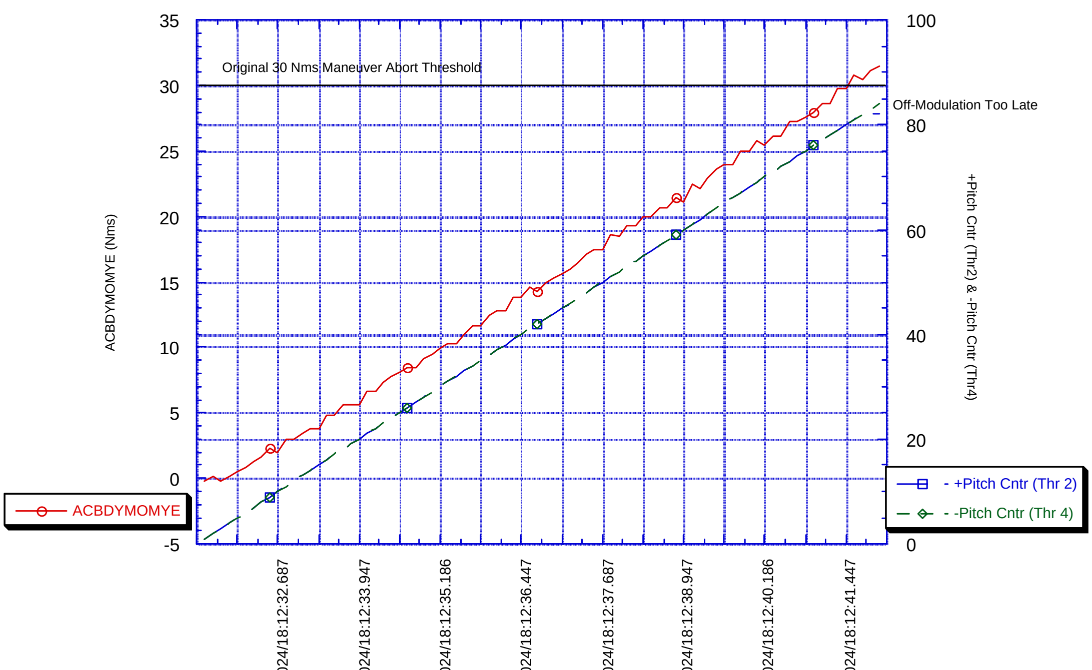


Figure 6.1-2 Example of Aborted LBS Delta-V Maneuver

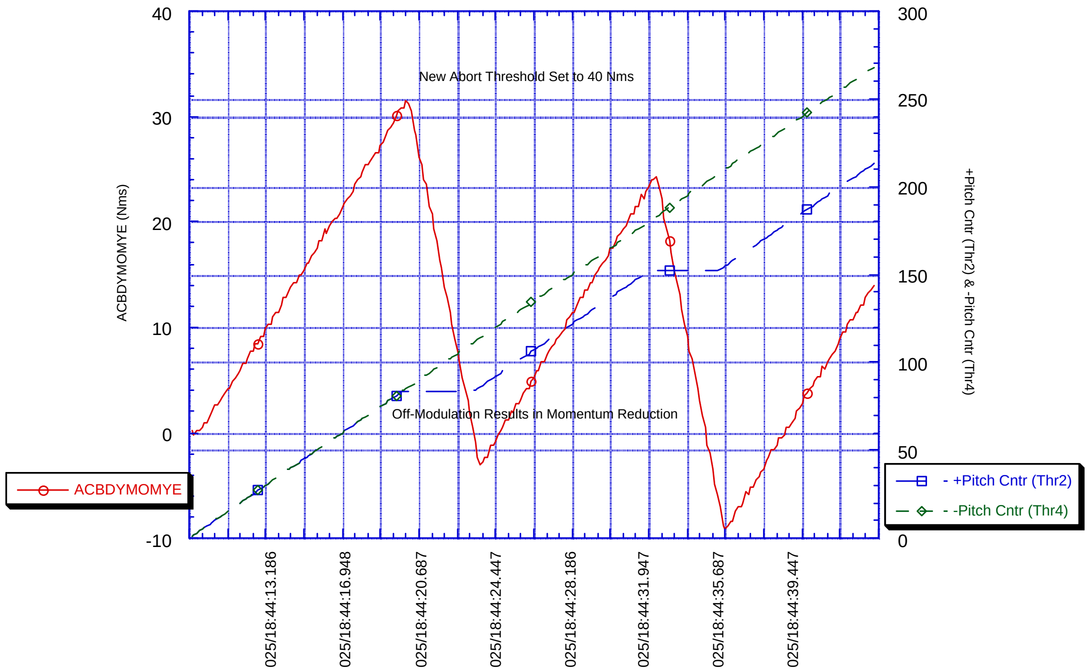


Figure 6.1-3 Example of Successful Thruster Off-Modulation

6.1.8 Yaw Maneuver Performance

180° yaw maneuvers are periodically performed to keep the +Y side of the Observatory out of the sun. The scheduling criteria uses the time when the spacecraft is within 1 degree of the zero beta angle while still in darkness. Three 180° yaw maneuvers and one 90° PR calibration yaw maneuver were performed in the first 60 days (see Table 6.1). Comparisons of simulated plots and those of the maneuvers show that the yaw maneuvers are performing quite well, especially the body rates and reaction wheel speeds. See Appendix E for a typical example of body rates and wheel speeds as demonstrated by yaw maneuver #3. Typically, it has taken about 16 minutes to perform the 180 degree turn and the subsequent return to Mission mode. The 90° duration is based on calibration requirements and orbit position. For real-time maneuvers, the high gain antenna (HGA) has been able to continuously track TDRS without any problems or dropouts.

Table 6.1 60 Day Yaw Maneuver Summary

MNVR #	DOY	DATE	MNVR DIRECTION	MNVR TYPE	MANEUVER START TIMES
1	347	13-Dec-97	+X to -X	180	13:10:00
2	348	14-Dec-97	-X to -Y to -X	90	11:45:00

3	014	14-Jan-98	-X to +X	180	20:48:00
4	029	29-Jan-98	+X to -X	180	23:30:00

6.1.9 CERES Calibration Performance

The series of six Inertial hold Deep Space calibration maneuvers for the CERES instrument were successfully conducted at the following times:

98-007: 13:07 - 14:38z, 16:10 - 17:41z, 19:13 - 20:44z
98-008: 13:30 - 15:01z, 16:33 - 18:04z, 19:35 - 21:07z

Real time coverage was added to monitor the transition back to Earth Acquisition through Mission mode. The ACS control algorithm worked as expected, maintaining an inertially fixed orientation for the required six orbits.

6.1.10 Remaining Tasks

All of the ACS checkout and calibration has been completed. There are some updated table generations which are awaiting final FDF calibration. These include the Gyro Bias Table and the TAM Alignment Table, both to be uplinked when ready, and the seven Backup versions of the IRU Alignment Table, which would only reside on the ground to be used if needed. After 60 days, all control modes except the Delta-H control mode have been tested and verified. Since Delta-H will only be used to unload extremely high momentum, there are no plans to test this mode. In addition, there is a possible influence, although very slight, on ACS performance in the form of slightly noisier position and rate errors due to CERES Biaxial operations. There is no impact to operations, but this will continue to be investigated further.

6.2 Power Subsystem

The Power subsystem has met all specified requirements. The Observatory load is maintained throughout each orbit and ample power is supplied to each subsystem through the electrical busses. The solar array and battery output have exceeded requirements.

6.2.1 Launch to Mission Mode

At lift-off Battery-1 state of charge (SOC) was 98.46% and Battery-2 was 98.47%, they discharging at approximately 5 amps per battery, and the temperatures were 22.37 °C and 23.16°C, respectively.

The batteries were charged to 100% SOC before the first eclipse. A maximum DOD of 60% was planned for any contingencies after separation. Due to the low tip-off rates

TRMM was able to acquire the Sun and the arrays began providing current for the Observatory load and charge for the batteries within 14 minutes.

PSIB-A and PSIB-B were both configured ON for launch. PSIB-A was used for charge control. PSIB-B was powered OFF at 98-332-17:23.

6.2.2 Mission Mode

The Power subsystem has performed well for all observed beta ranges. The maximum DOD has been between approximately 14% and 16%; this is well below the specified maximum allowed of 25%.

TSM #2 was generated an event at 98-008-00:50:58 because the PSIB-A Battery-2 state of charge was low for one telemetry packet (Anomaly #49). The PSIB is known to drop individual cell voltage, battery state of charge, and other telemetry for one count. TSM #2 was also tripped on 98-008 and 98-009 and TSM #1 was tripped on days 98-016 and 98-020. Event status messages will be generated up to four times for the single trip, then event messages will only be seen if an action is taken or if the TSM is reset. PSIB SOC dropouts continue to occur, as well as, cell voltage dropouts.

On 98-028 Battery-2 Cell 1 began hitting Yellow high limits of 1.49-1.52 V as the batteries hit the VT limit (Anomaly # 55). When the Battery-2 Cell 1 voltage reaches its peak, it is 50 to 80 mV higher than any other battery cell. Trending the daily maximums for cell voltages, Battery-2 Cell 1 has slowly increased since launch (see Figure 6.2-1). Plans are being discussed to change the charge current and VT level. Investigations into temperature, high charge current, telemetry errors, and inherent cell acceptance data are ongoing.

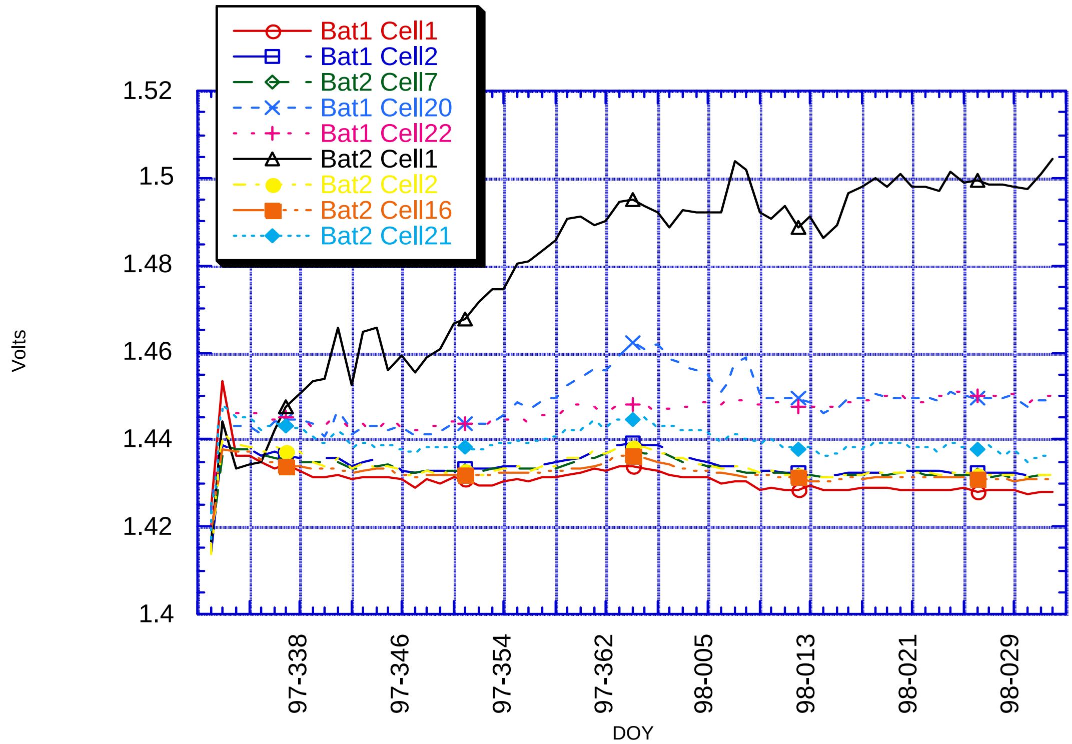


Figure 6.2-1 Battery Cell Voltage Peaks

6.2.3 Charge Cycle

The battery charge cycle is at a step-to-charge setting of peak power track. The initial battery charge current at start of orbit day is as high as 46 amps. Although high for a 50 amp-hour battery, it is still within an acceptable range. This high charge current will be investigated with the battery cell anomaly as a possible cause for the degradation of Battery-2 Cell 1.

The batteries are operating under VT control at a setting of VT 5. The VT limit is reached early in the charge cycle after charging at peak power track for 5 to 10 minutes. The batteries are then charged at a VT taper until the C/D is reached, 1.045, when the state of charge for both batteries is at 100%. The batteries are charges in a VT taper for 16-20 minutes. The step-to-trickle setting is 0.75 amps (0.375 Amps per battery) for a charge period of approximately 33 minutes. A typical battery charge cycle for an orbit is shown in Figure 6.2-2.

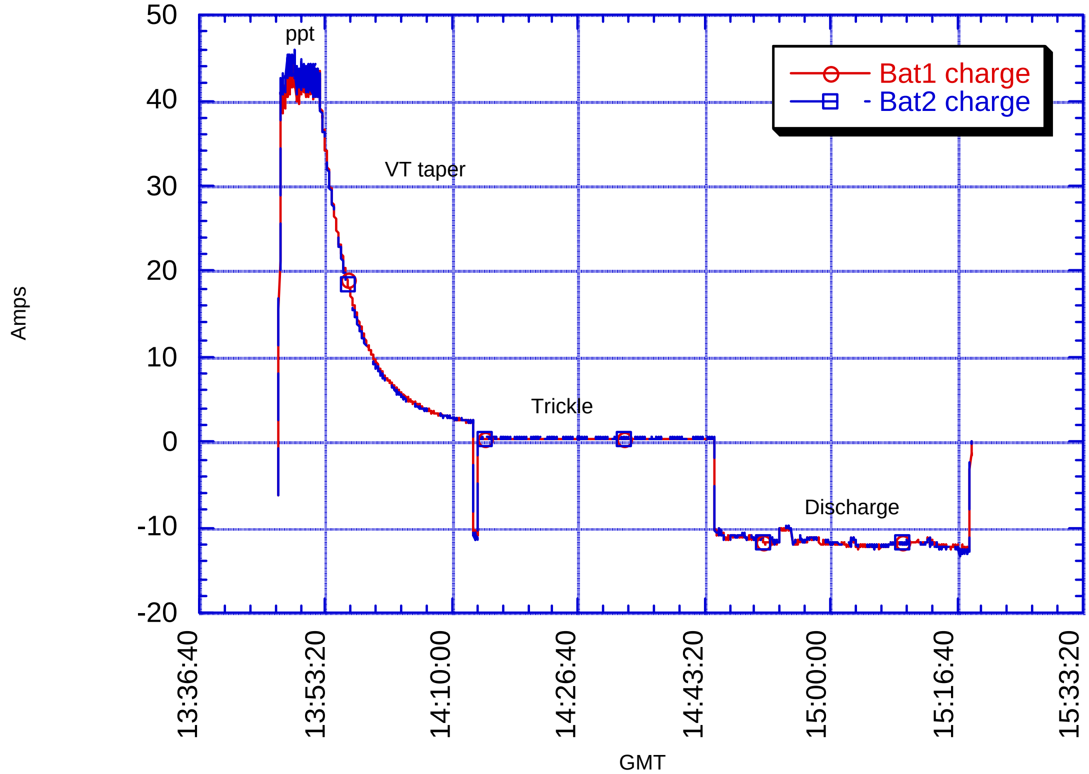


Figure 6.2-2 Typical Charge Cycle (Orbit #625 on 98-006)

The on-orbit solar array output is approximately 3700 Watts. This output has been consistent through checkout and does not show any apparent degradation. The solar arrays were designed to carry an 1100 Watt load. There is plenty of power margin between the load demands and actual load provided.

The essential bus voltage varies from about 32.4 V (0.7 V higher than the batteries) to 27.5 V (0.2 V lower than the batteries). The batteries are required to provide a bus voltage of 28 ± 7 V.

Battery temperatures have been stable. Battery-1 operates between 5.8°C and 10.8°C. Battery-2 operates between 8.8°C and 12.2°C. The battery specified operating temperature is above 5°C. The temperature varies with the beta angle with the highest battery temperatures occurring near beta angle 0° (see Figure 6.2-3).

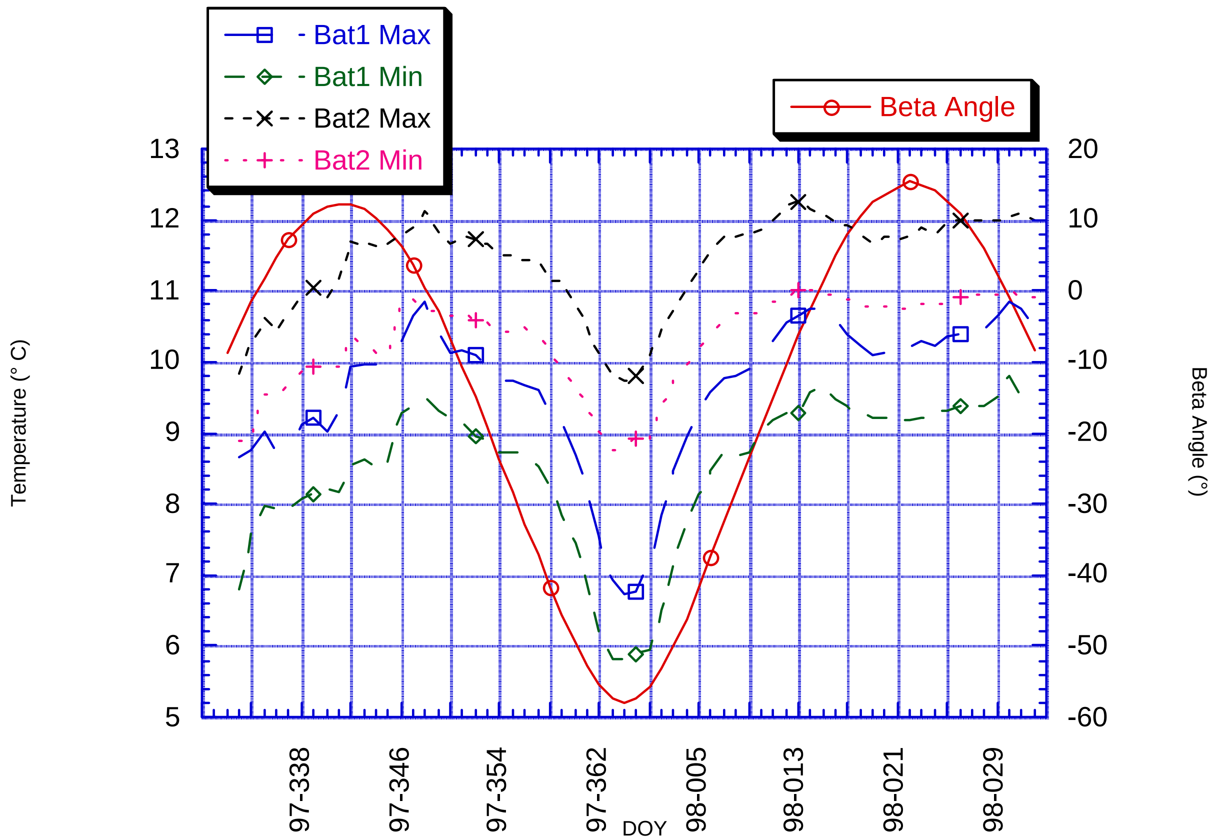


Figure 6.2-3 Battery Temperatures and Beta Angle

6.2.4 PSIB Day/Night Knowledge

There were initially several issues regarding the PSIB day/night flag. The PSIB uses three values to determine whether it is day or night: Solar Array Voltage, Solar Array Current, and Solar Array Temperature. If the Solar Array Voltage is below 80 V *and* the Solar Array Current is less than 10 amps *and* the Solar Array Temperature is below 65° C then it is PSIB orbit 'night'. If any three of these values are above these limits then it is 'day'. The same values are used for both 'day' and 'night' detection, and there is no minimum time for which a value must be above or below a threshold before 'day' or 'night' is declared.

Initially the Solar Array Voltage threshold was set at 45 V. Immediately before dawn it was believed that some light would filter through the atmosphere, and the solar array voltage would climb above 45 V without producing appreciable current from the arrays. Since the solar array voltage was over the voltage threshold, this was seen as the start of 'day' by the PSIB. Occasionally the voltage then dropped below 45 V before the current had reached 10 amps, changing the PSIB state back to 'night'. It then set the end of day state of charge to the current battery state of charge. Since eclipse was just exited, this state of charge was very low, causing the appearance of a dangerously low end of day battery state of charge. It also caused problems with the VIRS instrument (Anomaly #43, for more information see section 7.2), since the FDS used the PSIB time in night flag to control the VIRS day/night mode transitions. Setting the PSIB day/night voltage threshold to 80 V corrected this problem.

Changes in Solar Array temperature are not immediate. Therefore, the PSIB day/night state does not change to 'night' immediately upon entrance into eclipse. Since the batteries begin discharging before the solar array temperature drops below the 'night' threshold, the battery end of day state of charge is not 100%, even if the batteries were fully charged at the start of eclipse. Because of this, the end of day battery state of charge is typically 99.6%.

6.3 RF/Communication Subsystem

There have been no major anomalies for the RF subsystem since launch. TRMM has been communicating with a strong signal and has not lost any data due to spacecraft communication problems.

6.3.1 Initial System Checkout

The spacecraft was launched with the primary transponder configured through the Omni antennas to provide the best link margin for the initial acquisition (by using the power amplifier). The first acquisition occurred as expected without difficulty, and the signal was very strong with signal-to-noise ratios slightly better than expected (Eb/N0=23.0).

GN/DSN capability was successfully proven in the first days after launch and allowed the recorded launch data to be downlinked before HGA operations were possible. Dropouts in detector lock were experienced during the first AGO event and it was determined that they were due to the strength of the forward signal (1 kW). The forward power level was 55 dBm, which surpassed the 54 dBm threshold for TRMM. A DSN event was scheduled to test the effect of a 16 W forward and was executed without difficulties. A later-scheduled AGO event overlapped an ongoing TDRS event with the assumption that the strong GN forward would overpower the TDRS signal and therefore would not require the TDRS event to be terminated first. This proved incorrect and the spacecraft could not be commanded successfully during the event because the receivers remained locked on the TDRS forward link. It appears that once the TDRS signal is locked, it is powerful enough to remain locked until terminated. In the future, overlapping events in this way will be avoided.

The reconfiguration of RF switch #4 from Omni to HGA on 97-332, at 22:12, was successfully performed while operating on transponder 2 (which does not use switch 4) to allow for high rate operations (data dumps). No problems were encountered.

During testing of the HGA on 97-333, after changing to high rate operations (32/2048 kbps), the antenna was run to the X-axis software stops at 20:45 to examine tracking and signal performance. The signal remained locked for approximately 2+ minutes after the end of track (~ 9° past stops), which was predicted as best case. This extra margin allows a little more flexibility with antenna view periods if necessary.

6.3.2 Operations

Dropouts due to RFI, false locks, and late acquisitions have been experienced regularly, as expected, and have not caused any data loss. False locks and late acquisitions have been successfully cleared with forward reacquisitions, when performed. During two events, dropouts were experienced over Japan due to a large amount of RFI. After investigation, it was found that the times of the interference correlated with times of scheduled ARC passes for the PR instrument (which were cancelled due to weather). The ground reference location of the TRMM spacecraft matched that of the ARC and seemed to indicate that the ARC signal had a large impact on the RF signal. Further investigation is ongoing. Numerous blind acquisitions have also been performed successfully on all four TDRS satellites. These included the first week of events scheduled on TDRS-7 (171), before AOS and LOS sequences were placed in the daily loads, and events scheduled for recorder management.

Anomalous behavior has been experienced with the forward signal of TDRS Spare since the beginning of the year (Anomaly #58). The behavior appears to affect the command lock most of the time, intermittently dropping lock during events, sometimes repeatedly. It also affects the receiver and PN long code locks occasionally. These lock losses can cause the transmitter to transition to non-coherent mode until the forward locks again. This has been experienced with both transmitters and only with TDRS Spare. It could indicate possible PN code problems (ADPE, EPV, etc.). Investigation continues into the cause.

TRMM was launched with an uplink frequency of 207694152 dHz (207694153 dHz to designate XP2 events for FDF). Trending the center frequencies for both transponders shows that XP1 has been less stable than XP2 (see Figure 6.3-1). XP1 drifted aggressively ahead of the uplink frequency (approximately 1200 Hz), approaching the TDRS acquisition threshold of 1500 Hz XP2, on the other hand, was relatively stable, staying at approximately 350 Hz behind. It was determined that the most efficient action would be to change the uplink frequency at the NCC to match that of XP1 since this is the one used most for operations, making the new frequency 207694254 dHz. Then XP2 would be offset to match the new frequency (new frequency of 207694255 dHz) to keep it within the acquisition threshold. After the changes were accepted by the NCC in mid December, several events were scheduled over the next month to test them and were executed successfully. The changes became fully implemented starting on 98-012, and transponder 2 was offset to match the new frequencies at that time. This appeared to be successful for the first low rate (XP2) event after the offset, showing a measured frequency of approximately 100 Hz ahead of the forward. Two weeks later, an LOF report was received indicating that the offset was no longer in place. The offset was attempted again at this time and again was successful for only one event. The offset does take effect but is then lost for the next event. This “forgetting” behavior was experienced on RXTE, causing them to lose the offset at the end of the event (deacquisition/power-off) and forcing them to place the command in all AOS sequences. Investigation continues into whether this is the same type of “forgetting” behavior or a separate anomaly.

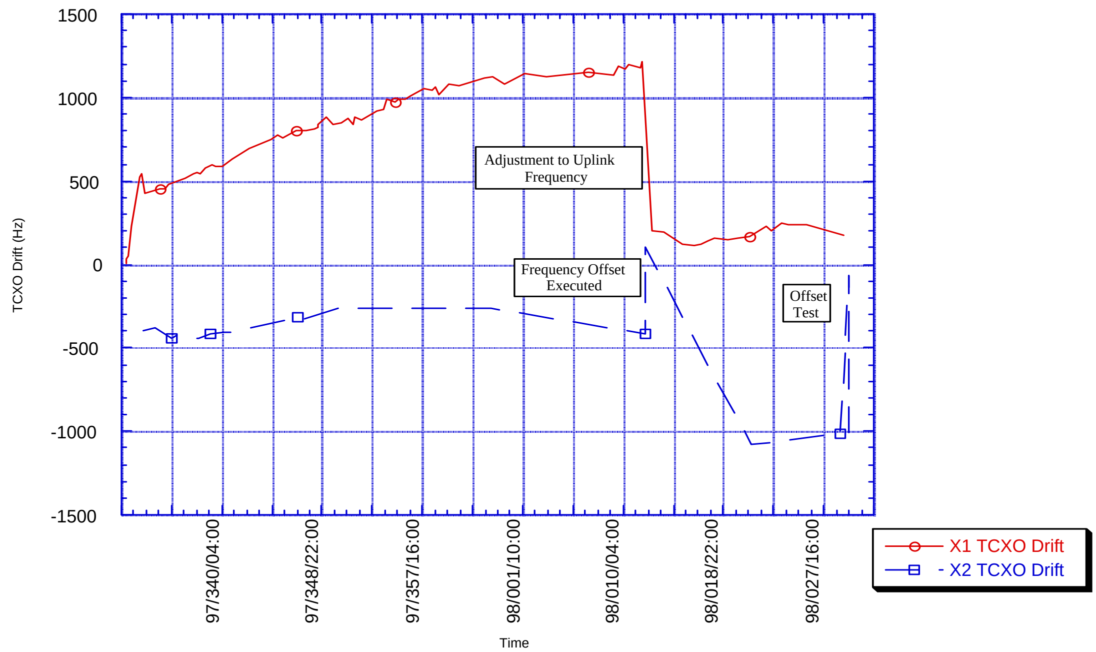


Figure 6.3-1 TCXO Drifts

The TCXO temperatures are showing obvious dependency on the Beta angle, varying sinusoidally with the Beta angle (see Figures 6.3-2 and 6.3-3). The fluctuation is approximately 3.5°C, with XP2 running 1° warmer than XP1. The oscillators are warmest when the Beta angle reaches it’s maximum (absolute) and coldest when the Beta angle equals 0°. Both also show an upward trend of 1.5°C per cycle as the Beta sinusoidal trends upwards. Temperatures are relatively constant between times when the Beta angle crosses 0°, increasing when Beta decreases and vice versa. At this time, the TCXO drift does not appear to be significantly affected by the temperature fluctuations.

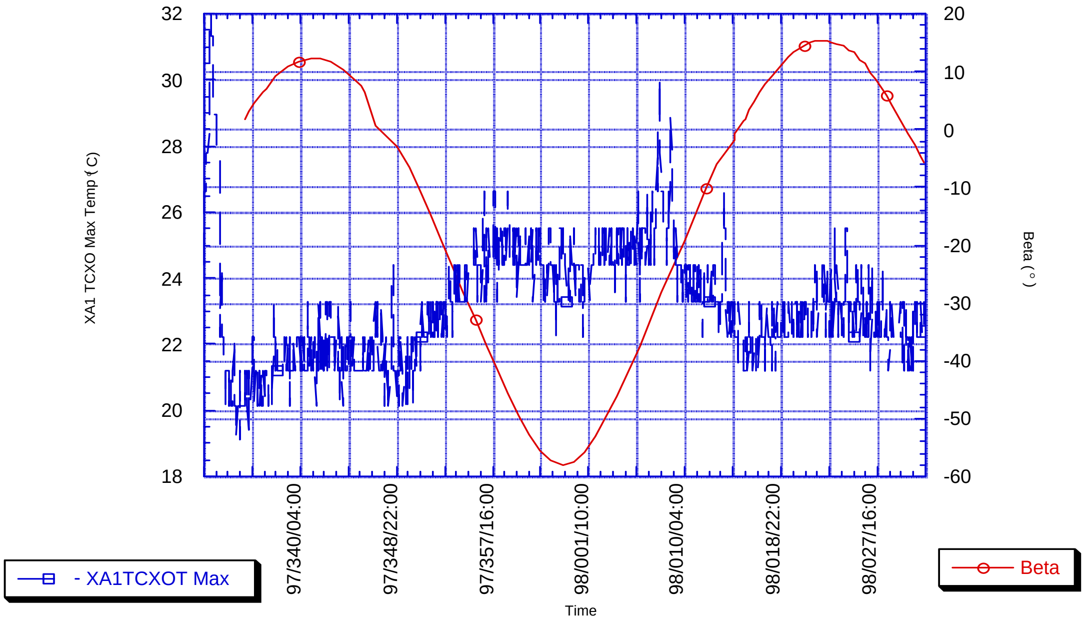


Figure 6.3-2 XA1 TCXO Max Temp. & Beta Angle

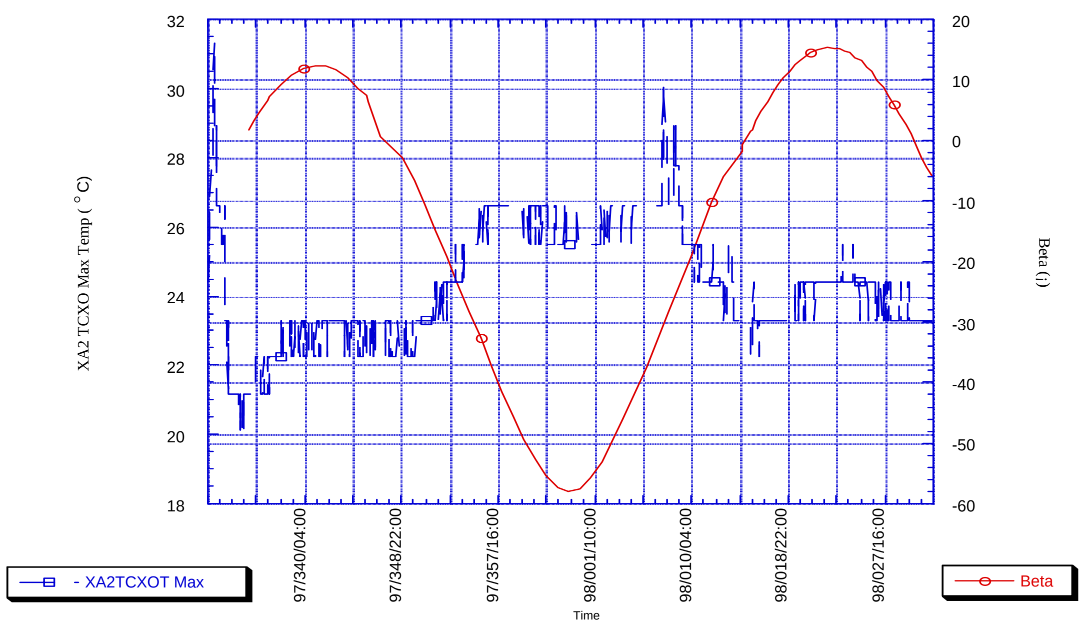


Figure 6.3-3 XA2 TCXO Max. Temp. & Beta Angle

6.4 DEPLOYABLES

The TRMM Deployables subsystem operational evaluation period was a success. The initial deployment and subsequent transition to full operational use of the solar arrays and high gain antenna were conducted without any problems, although there was an initial concern regarding the full deployment of the high gain antenna boom. Regular trending of component health and safety, such as seasonal thermal variations of the solar array drives, continue to be performed by the FOT. In addition, operational improvement evaluations are regularly conducted. One such result is the possibility of limiting the solar array range of motion to ± 50 degrees centered about eclipse times. The power margin is sufficient to allow for this, the duty cycle on the drive bearings would be reduced, and the reduced atmospheric drag should increase mission life on the order of months.

6.4.1 Deployment

On 97-331-21:42:12 and 21:42:13, the +Y and -Y solar arrays were successfully deployed, using pyro-actuated pinpullers. The IPSDU TMM then activated the GSACE-A DCM sequencer which was responsible for indexing the +Y solar array 180° to be parallel with the -Y array. Full deployment was immediately identified, and then confirmed when the ACS Sun Acquisition control mode was achieved.

At 21:42:14, the high gain antenna deployment system (HGADS) was also autonomously released, using four pyro-actuated pinpullers. Approximately 30 seconds later, the Deployables Engineers verified the HGA had finished moving. The potentiometer readings for A and B were confirmed at 91.08° and 94.77° respectively. According to telemetry, positions indicated “Deployed”. At first, it was suspected that the HGA was not fully deployed since earlier launch rehearsal telemetry from the simulator consistently showed potentiometer readings of 110° (Anomaly #3). However, after reviewing 8 Hz gyro data from the time of the deployment, conducting on-orbit antenna RF tests with TDRS, and studying data from previous I&T tests, it was concluded that the HGA had latched into a locking position.

6.4.2 Checkout

On 97-332, the HGAS was tested by performing dummy tracks. During the HGAS dummy tracks, GSACE telemetry was monitored and commanding was performed through the Omni antennas. Several orbits of dummy tracks were performed and all were considered nominal, including the transition to and from the antenna feather position between contacts. As a result, on 97-332-23:38 the HGAS was first used for communication with Space Network using the TDRS West satellite. There were no problems acquiring TDRS at the scheduled Acquisition of Signal (AOS) and commanding was successful.

The solar arrays performed quite well during the transitions between day and night. The only exception is that the ACS software, which initiates the slews based on pre-dawn criteria, does not finish slewing the arrays until over a minute into the daylight period (Anomaly #20). The checkout of the solar array drives consisted primarily of monitoring the slew to feather before night and from feather to solar tracking as daylight approached. The arrays were also observed to stop as expected as the descent maneuvers were conducted, and then complete their slew to position once the maneuvers were complete. The solar array drive temperatures were also closely monitored, and were found to be dependent on the solar beta angle (see Figure 6.4-1). No limit violations were triggered during this phase.

6.4.3 Normal Mission

The HGA is now used as the primary means of communications. It has operated with no anomalous behavior. During realtime RCS thruster operations and ACS yaw maneuvers, there has been no loss of RF lock while operating on the HGAS. The HGA remains feathered when out of contact with TDRS and during events with the omni antennas.

The HGA X-axis reached its software stop of 90.2° on 97-333 causing the event to be terminated approximately two minutes early (Anomaly #14). The reason was related to operations. The events for the first few days of launch were scheduled using PSAT files, which only contain orbit information, rather than the more accurate UAV files, which also include the HGA keyhole and masking data. All events are now scheduled using the UAV files. On 97-363-07:29, then again on 97-024-14:42, playback flight status messages indicated that the HGA reached the software stop again. These messages proved inaccurate, however, because the HGA was feathered at the time they occurred. As it turns out, the messages actually resulted from one update of a bad GSACE packet (Anomaly #46). There has been no impact to operations from this anomaly. No violation of the HGA Y-axis software stop has occurred.

The solar array tracking also continues to perform nominally during normal eclipse transition operations and maneuver operations, although there is one area of concern. The solar beta angle reached a worst case of -58° during winter solstice on 97-364. The -Y solar array actuator temperature peaked at 41.4 °C, one degree below the YH limit, during the week prior to and after that point (see Figure 6.4-1). This trend is of long-term concern because drive motor lubrication could degrade and evaporate if the bearing temperatures, which cannot be measured directly, are higher than expected. Long term analysis of this condition, along with more data gathering from other missions, is being conducted to try and avoid any potential problems in this area. Furthermore, a study is under way to determine the feasibility of limiting the array range of motion to only ± 50°.

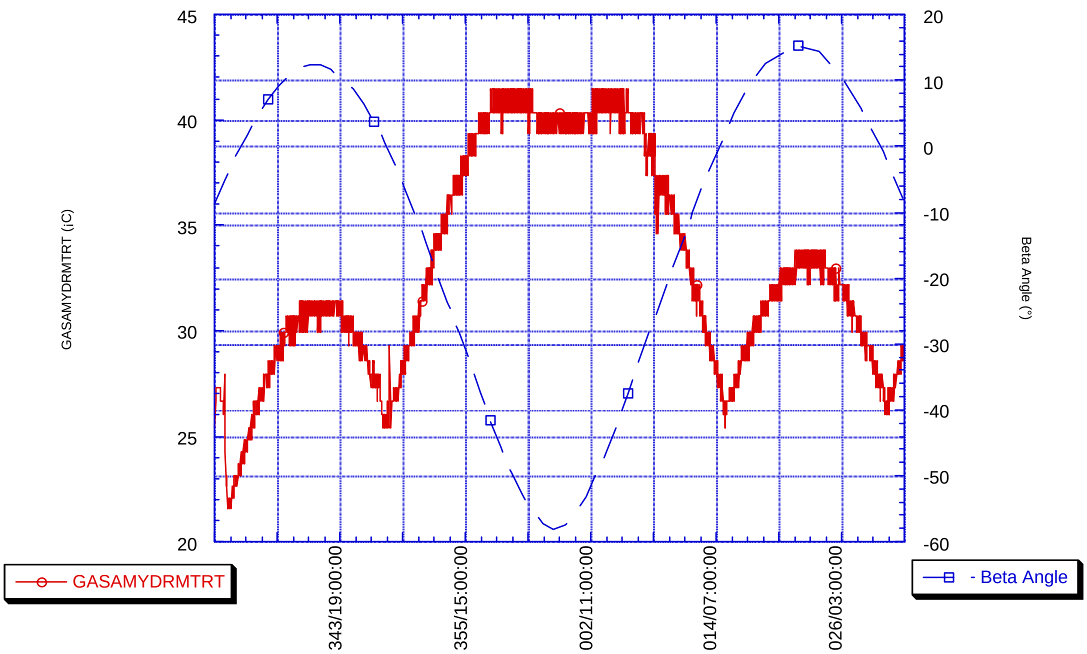


Figure 6.4-1 Maximum -Y Solar Array Drive Temperature vs Beta Angle

6.5 Reaction Control Subsystem (RCS)

The Reaction Control subsystem, which consists of the fuel and pressurant tanks and lines, the various thrusters and valves, as well as the corresponding heaters was thoroughly evaluated during the TRMM 60 day checkout period. Analysis of the performance indicates the system is behaving nominally.

6.5.1 Initial RCS Operations

In preparation for launch, Isolation Valves 1 through 4 were opened on 97-331-11:30. After launch, isolation valve #5 (tank cross-over valve) was opened on 97-332-01:25. At 15:45 on 97-332 the primary pressurization pyrotechnic valve was fired, allowing high pressure Nitrogen gas to reach the regulator inlet. The redundant pyrotechnic was left in an unarmed and unfired state. The pressurization of the propellant tanks by the regulator was nominal.

Several of the thruster catalyst bed temperatures were slightly higher than predicted by the TRMM thermal model while in the inertially fixed sun acquisition mode (Anomaly #1). The differences between the thermal predictions and on-orbit readings were due to the assumptions made in the thermal model about the surface properties. However, the catbeds are designed to operate at extremely high temperatures, often reaching temperatures of 600 °C during a burn, and the slight deviation from the model represented no hazard to the Observatory. Table 6.5-1 contains a summary of the 13 calibration, descent, and stationkeeping maneuvers or maneuver pairs which occurred during TRMM's 60 day checkout period.

6.5.2 Calibration Phase

On 97-332, the roll thrusters were calibrated by sending a single 200 ms pulse to each thruster and then verifying the proper change in momentum. Since then, disturbances have been low enough during each maneuver that the roll thrusters have not fired again.

On 97-333, the ISP thrusters (#5 through #8) were calibrated by performing a 10 second Delta-V firing. The Delta-V was successful, but the -Pitch thruster was only on for 7 of the 10 seconds (Anomaly #18). On 334-15:11 ISP thrusters were re-tested with a similar result of 7.5 seconds. Initial simulations predicted that all four Delta-V thrusters would be commanded on for the entire 10 seconds. For such a short duration burn it was not believed that the disturbances would cause the attitude errors to reach the switching limits.

When these switching limits are reached, the ACS automatically off-modulates the appropriate thruster. Slight differences in the assumptions for center of mass, thruster alignment, thruster positions, and thrust levels will cause slight variations in the time required to reach the -Pitch switching limit. It should be noted that the center of mass is above the x-y plane, so some net -Pitch torque is expected. This has held true for every maneuver so far, with an on-time average of 67% for the ISP -Pitch and LBS +Pitch thrusters. When the anomaly report was first written, it was believed that solar array slew timing was the major cause for the torque disturbances which caused the off-modulation. This theory has since diminished, because the off-modulation has occurred for every maneuver, regardless of the solar array slew status. All RCS thruster and ACS control performance is within the expected range.

On 97-335, the LBS thrusters (#1 through #4) were similarly calibrated by performing a 10 second Delta-V firing. This operation was successful with no off-modulation of any of the thrusters.

The final calibration/test consisted of a 60 second burn, which also doubled as a descent burn, using the ISP thrusters to further verify ACS/RCS operation for the remaining descent burns. This was successful, with a 67% duty cycle seen on the -Pitch thruster.

6.5.3 Descent Phase

Eight descent burns were performed on 97-338 through 97-341 to lower TRMM from 380 km to its nominal 350 km orbit, including the final 60 second calibration burn. All were performed using the ISP thrusters due to the timing of the yaw maneuvers. Since these burns were all successful, no additional trim burn was required.

6.5.4 Stationkeeping Phase

Four pairs of Delta-V stationkeeping firings were performed during the first 60 days after launch, once mission altitude was attained. The last pair was performed following a yaw maneuver transition to the +X forward orientation, so that the LBS thrusters were used for the first time since the 10 second calibration burn on 97-335. As it turned out, there was a high degree of initial body momentum in the pitch axis as the burn was performed. The off-modulation of thruster 2 (+Pitch) did not occur before the 30 Nms FDC maneuver abort level was reached. As a result, the maneuver aborted 10 seconds into the planned 39 second burn (Anomaly #52). Later analysis showed the off-modulation (and corresponding momentum reduction) was just missed by a matter of a few control cycles. It was then decided that the 30 Nms maneuver abort limit was too tight, and the pitch momentum value in ACS System Table #73 was increased to 40 Nms. The maneuver was then successfully performed the following day (98-025). It was later decided to further increase the FDC abort level to 45 Nms, because trending analysis showed that the pitch momentum reached as high as 38 Nms during the second half of the LBS Delta-V maneuver pair. See Section 6.1 for sample plots which compare the aborted maneuver with a nominal LBS off-modulating maneuver.

6.5.5 Fuel Budget Analysis

Prelaunch fuel consumption predictions were calculated using a nominal regulated pressure of 170.0 psia. Observed data shows this value is really closer to 167.7 psia. Figure 6.5-1 shows how the actual versus predicted fuel consumption values have diverged nearly 1 kg in the first 60 days. Using this data in conjunction with the January 98 Schatten Solar Flux predictions (the new magnitudes are almost 16 units higher for the 2σ case compared with October 97 predictions) , the 2σ prediction for science mission length beyond three years is +166 days. The initial fuel level for TRMM was 890.0389 kg. Approximately 23.8 kg of hydrazine fuel was used during the calibration and descent maneuvers. After the pair of LBS stationkeeping burns was performed on 98-025, TRMM had used less than 31 kg of fuel, and still had 859.1 kg of hydrazine remaining (see Table 6.5-1 below).

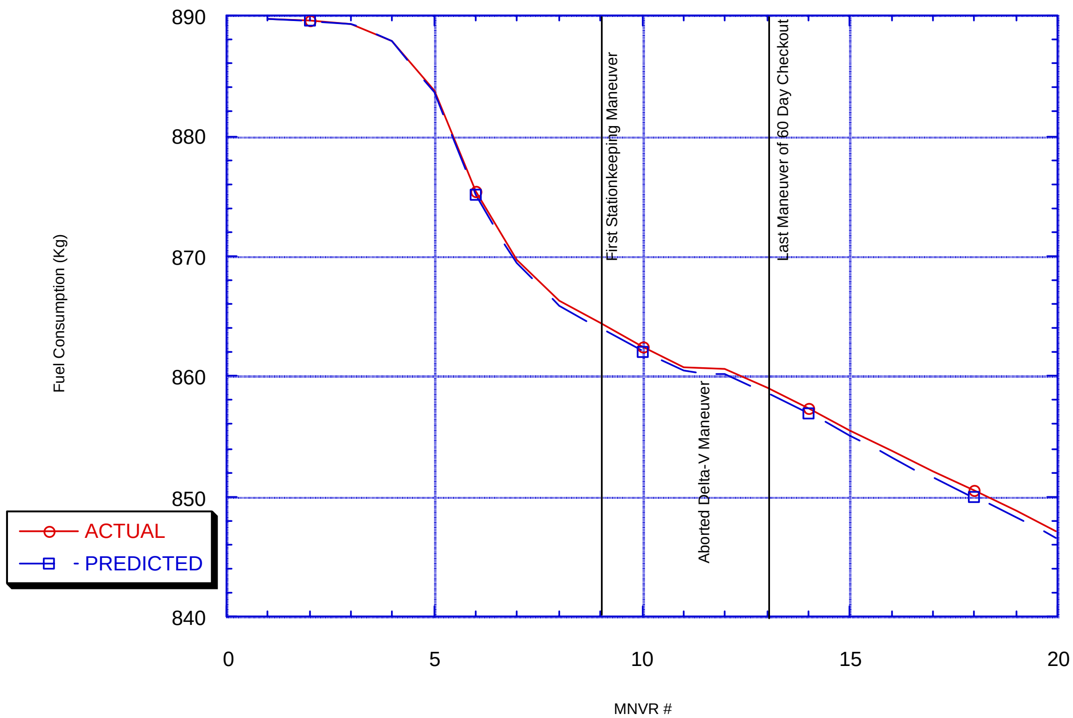


Figure 6.5-1 Actual and Predicted Hydrazine Fuel Consumption

Table 6.5-1 TRMM Delta-V 60 Day Summary

MNVR #	DOY	DATE	MANEUVER TIMES	MANEUVER TYPE	THR SET	FUEL (kg)
	332	28-Nov-97	14:15:46	200 ms Roll Thruster Pulse	9	890.0389
	332	28-Nov-97	14:18:14	200 ms Roll Thruster Pulse	10	890.0389
	332	28-Nov-97	14:20:00	200 ms Roll Thruster Pulse	11	890.0389
	332	28-Nov-97	14:22:56	200 ms Roll Thruster Pulse	12	890.0389
1	333	29-Nov-97	17:58:00 - 17:58:10	10 second Calibration Burn	5-8	889.8026
2	334	30-Nov-97	15:11:00 - 15:11:10	10 second Calibration Burn	5-8	889.5631
3	335	01-Dec-97	15:03:00 - 15:03:10	10 second Calibration Burn	1-4	889.3076
4	337	03-Dec-97	19:35:00 - 19:36:00	60 sec Cal/Descent Burn	5-8	887.9194
5	338	04-Dec-97	20:07:00 - 20:10:00	Descent Burn	5-8	883.7220
6	339	05-Dec-97	19:05:00 - 19:08:00 / 20:37:00 - 20:40:00	Descent Burn Pair	5-8	875.3373
7	340	06-Dec-97	18:54:00 - 18:57:00 / 20:26:00 - 20:27:00	Descent Burn Pair	5-8	869.7533
8	341	07-Dec-97	17:43:37 - 17:44:58 / 19:28:41 - 19:29:50	Descent Burn Pair	5-8	866.2544
9	353	19-Dec-97	18:08:46 - 18:09:43 / 18:57:43 - 18:58:05	Stationkeeping Burn Pair	5-8	864.4134
10	001	01-Jan-98	18:17:33 - 18:18:23 / 19:03:20 - 19:03:54	Stationkeeping Burn Pair	5-8	862.4729
11	012	12-Jan-98	18:14:15 - 18:15:03 / 19:00:07 - 19:00:30	Stationkeeping Burn Pair	5-8	860.8126
12	024	24-Jan-98	18:12:30 - 18:13:09 / (Aborted at 18:12:40)	Stationkeeping Burn Pair	1-4	860.5452
13	025	25-Jan-98	18:44:09 - 18:44:42 / 19:29:50 - 19:30:18	Stationkeeping Burn Pair	1-4	859.0768

6.5.6 Thruster / Valve Performance

Data from the FDF indicates that the thrusters are providing 5% greater thrust than originally modeled. Catbed temperatures also increased as expected, reaching a maximum level of nearly 600 °C. The Catbed heaters also have performed nominally. The Catbed heaters are turned on 91 minutes prior to each stationkeeping burn, but typically reach the minimum 32 °C requirement in less than an hour, depending on the initial temperature due to sunlight (see Figure 6.5-2). Furthermore, the temperature rise due to thruster valve soak back was only 10° on average. See Appendix E for more trend analysis of the thruster and valve temperatures.

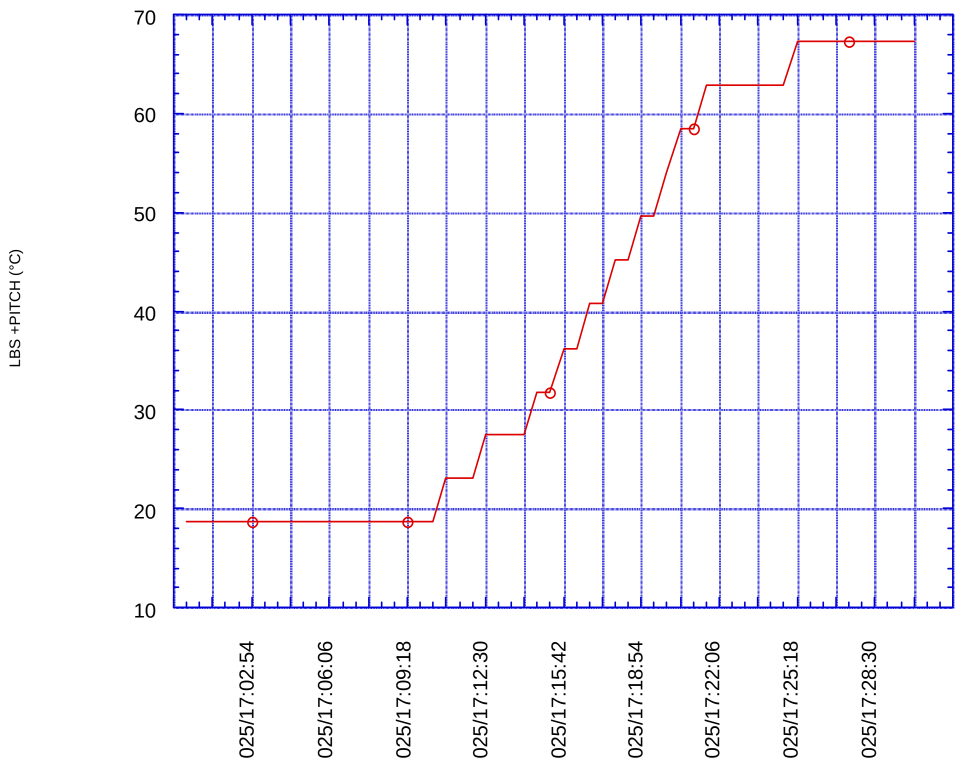


Figure 6.5-2 Catbed Warmup Following Heater Power On

6.5.7 Tank Performance

Fuel tank pressures and temperatures were nominal during the initial checkout period, averaging about 167.5 psia and 18.4 °C respectively. The propellant pressure remained constant throughout the burns at 165 psia on average, and returned to the pre-burn values of 167.5 psia. The pressurant tank value, which began at 3230 psia prior to launch, reached a steady value of 3051.6 psia at the end of the 60 day period after dropping more than 100 psia during the descent maneuvers. The tank heaters have not reached their 13 degree set point and have thus remained inactive to this point. The pressurant tank has seldom dropped below its heater set point of 23 degrees. However, as the solar beta angle has increased, the pressurant tank temperature has increased due to extended solar heating. The higher temperatures have not adversely affected operations. See Appendix E for the complete 60 day trend analysis for the tank temperatures and pressures.

6.5.8 Line Performance

TRMM's line temperatures were nominal during the initial checkout period. The fuel line temperatures decreased 4 to 7 °C on average as propellant flowed through the lines. The internal and external line heaters continue to provide adequate thermal stability to the lines, with an observed duty cycle of close to 50% for the setpoint of 23-24 °C. The only exception is RA_LN5_T (line #5 temperature), which has experienced a temperature gradient of only 2.5 °C over the entire 60 day checkout period. As with the pressurant tank, some line temperatures have been higher than expected due to extended solar heating. Figure 6.5-3 demonstrates a typical orbit for the Fill and Drain Module (FDM) heater's duty cycle, which has on/off setpoints of 17/22 °C. See Appendix E for the complete 60 Day trend analysis of the line temperature performances.

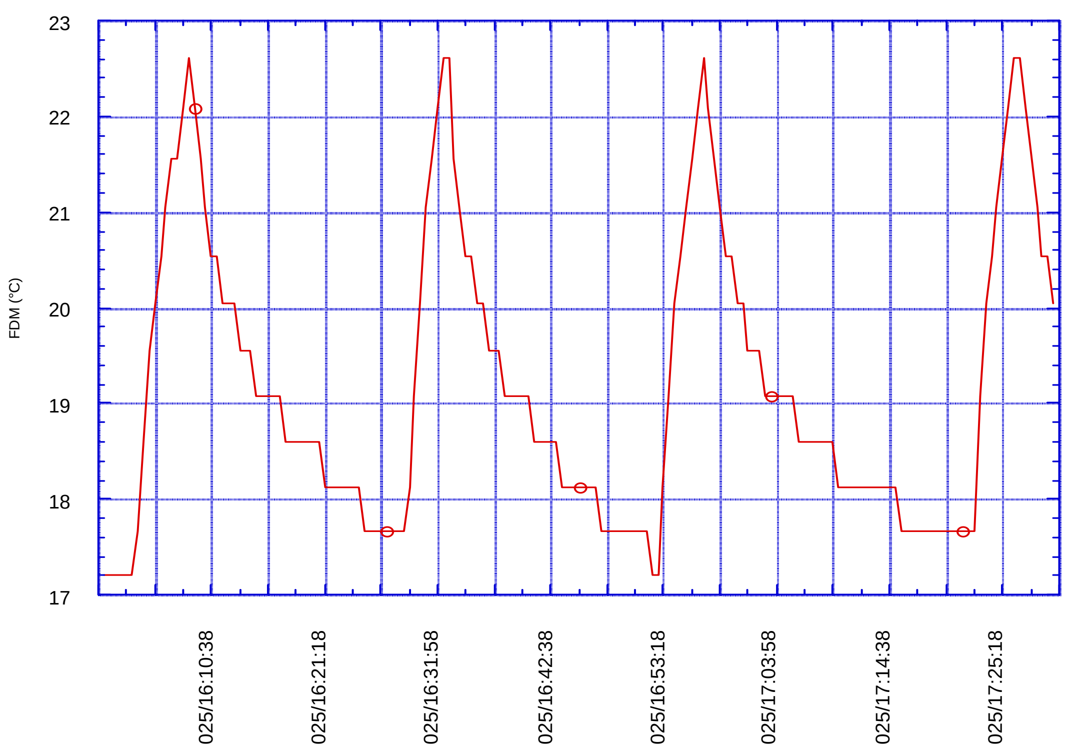


Figure 6.5-3 Typical FDM Heater Duty Cycle for one Orbit

6.6 Electrical Subsystem

The Electrical Subsystem has operated nominally during the first 60 days of the TRMM Mission. Fairing separation, Solar Array and High Gain Deployment, and pyro firings for the RCS and TMI were also performed successfully. For details on these activities, refer to the TRMM 14 day report. All instruments were powered on successfully over the next several days after launch, with current draw as expected. Configuration for mission mode proceeded nominally.

Non-Essential bus current remains stable with an average current of approximately 17 amps, and an average maximum current of about 22 amps with peaks up to 24.3 amps during Delta-V maneuvers, as shown in Figure 6.6-1. Note the increase in current as the instruments are powered up during the first couple of days after launch.

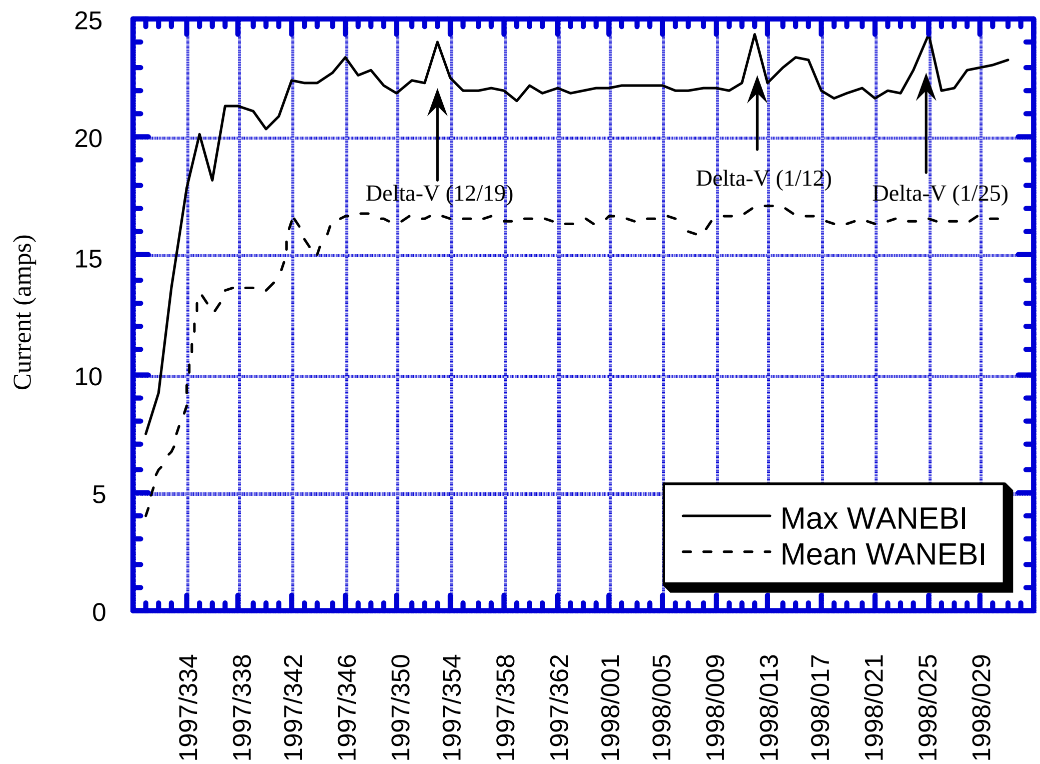


Figure 6.6-1 Non-Essential Bus Current

Essential bus current and voltage plots are shown in Figures 6.6-2 and 6.6-3, respectively. The mean essential bus current has remained stable at approximately 6 amps since a week after launch. Peaks seen in the maximum current are still being investigated. The average essential bus voltage has remained constant between 30 and 31 volts, increasing as the Beta angle increased to the maximum value of -58°.

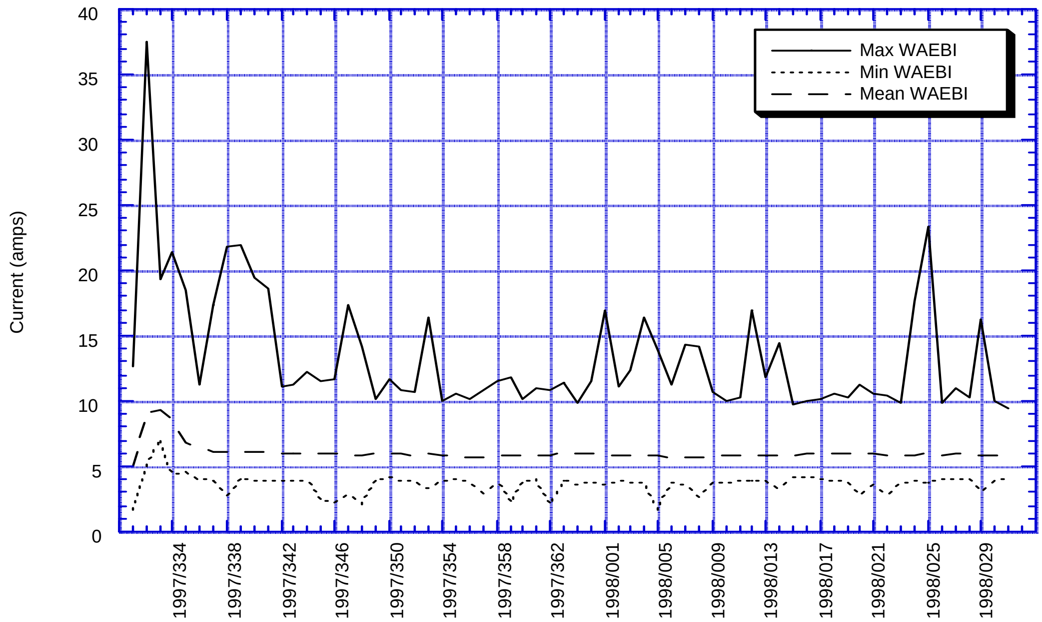


Figure 6.6-2 Essential Bus Current

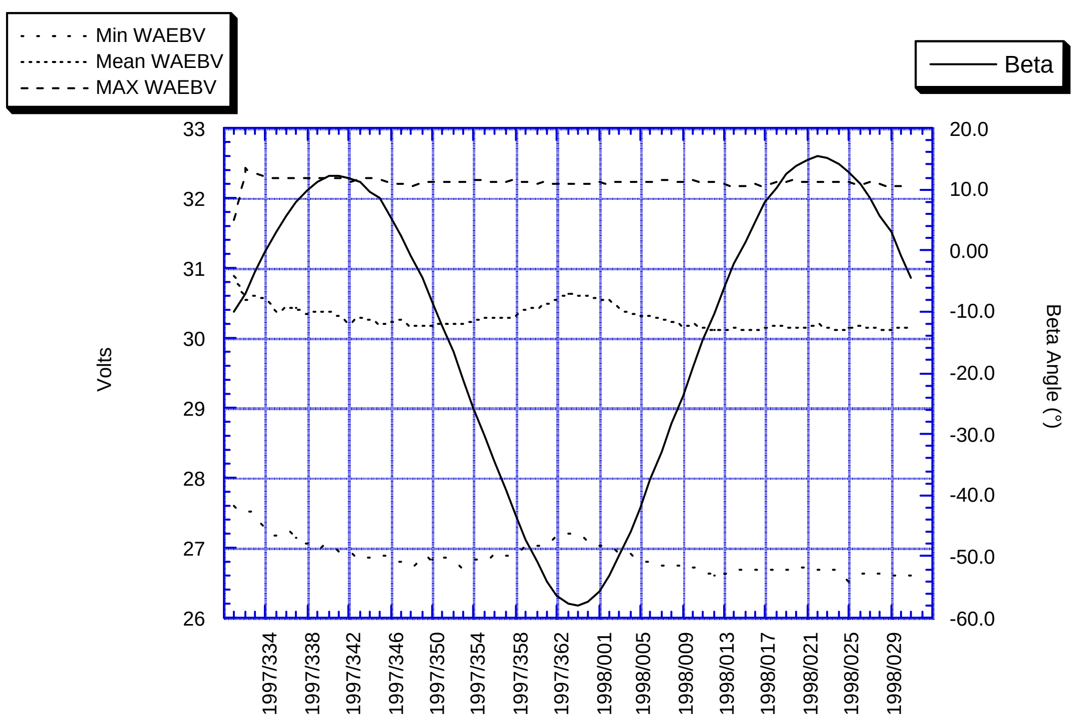


Figure 6.6-3 Essential Bus Voltage vs. Beta Angle

6.7 Command and Data Handling (C&DH) Subsystem

TRMM Command and Data Handling performance has been nominal, operating on the B-side Frequency Standard and Clock Card. There has been no indication that the anomalous behavior experienced with the A-side before launch exists on the B-side.

One 1773 retry error has occurred during the first 60 days. A 1773 bus retry error on the primary ACS processor Remote Terminal on the spacecraft bus (Anomaly #13) was detected on 97-332 at 17:38. The cause has not yet been determined

All three spacecraft 1773 busses have collectively been experiencing approximately three retries per day, which breaks down to one retry per bus, though the instrument bus is a fraction higher than the other two. Almost all retries have occurred in the South Atlantic Anomaly Region (see Appendix E for plots of the retries for all three busses).

Memory Scrub single-bit errors have been experienced at a rate of 75 per day (Anomaly #4) and multi-bit errors have been experienced regularly at the average rate of one every four days (Anomaly #33 - see Appendix E for plot and record of times and locations). These values are consistent with the radiation estimates for TRMM (Anomaly #4).

There was an anomaly experienced with the FS on 98-022 where the drift rate jumped to 13 microseconds an hour and remained there (see Figure 6.7-1). Once adjusted again using the clock drift data, the rate remained steady and there has not been a recurrence since. The cause has not yet been determined.

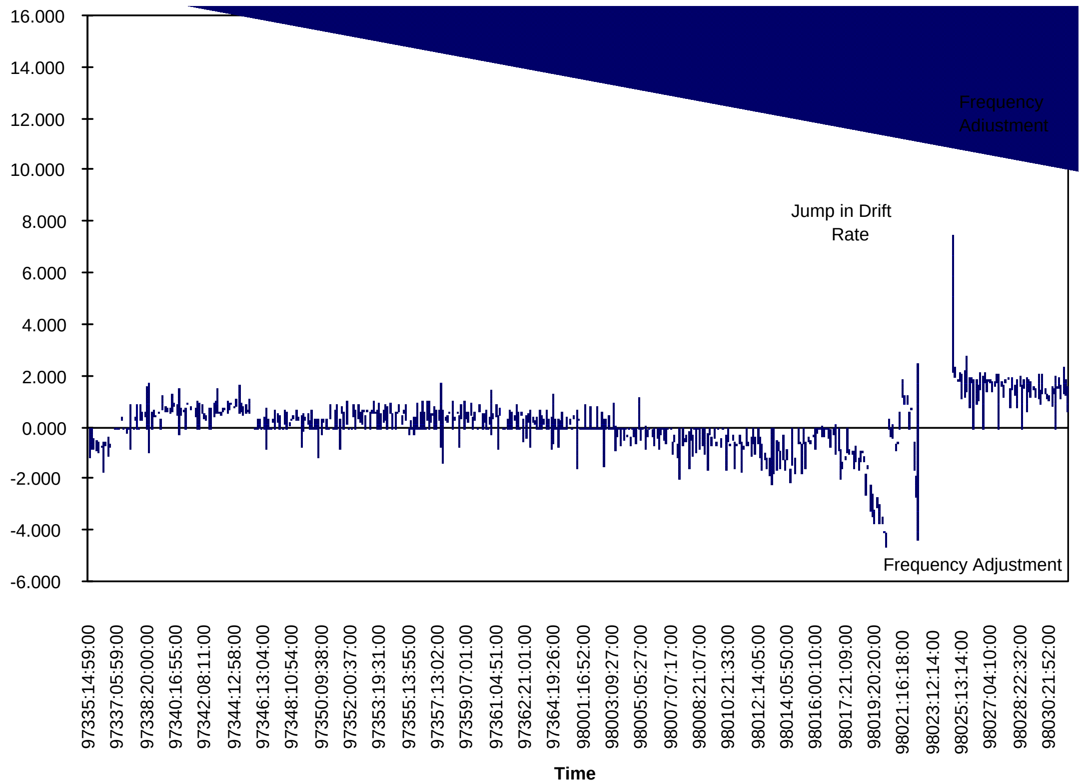
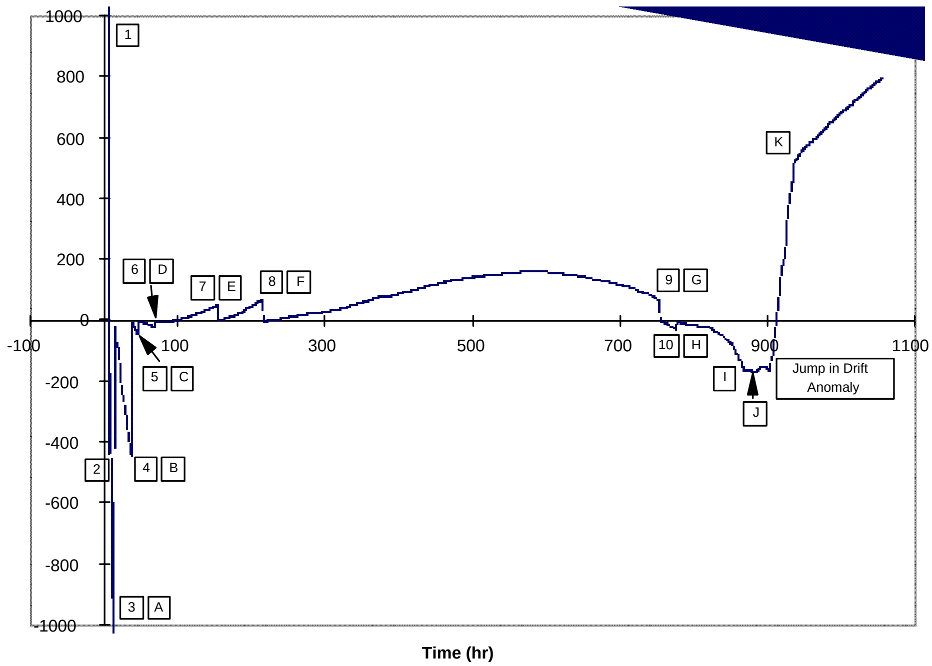


Figure 6.7-1 Frequency Standard Drift Anomaly

The initial approach of adjusting the clock to keep it as close to 0 μsec as possible was used throughout most of the launch and in-orbit checkout period. This philosophy was then changed on 98-015 to allow the clock to drift more freely within the 1 msec threshold (adjustments made at ~900 μsec) in order to trend the FS behavior in relation to the Beta angle. The clock drift has displayed a change from positive to negative drift when the Beta angle reaches 0°. By delaying adjustments until closer to the threshold, it is believed that better trending of this behavior can be performed. Investigation is continuing to determine if the interaction with the Beta angle will eliminate the need for adjustments (see Figure 6.7-2 and Table 6.7-1 for an overview of the clock activity).



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igure 6.7-2 Clock Activity for L&IOC

TRMM CLOCK AND FREQUENCY STANDARD DATA						
Reference	TIME (GMT)	Clock Adjustment	FS Adj (Cnts)	New FS (Cnts)	New FS (HEX)	Comments
	97331:21:27:00			1726.0	6BE	
1	97333:08:14:22	5144.1				
2	97333:10:16:09	-410.0				
A	97333:20:22:38		71.0	1797.0	705	
3	97333:20:29:36	-1147.0				
B	97335:02:01:11		27.0	1824.0	720	
4	97335:02:03:32	-442.5				
C	97335:13:20:27		6.0	1830.0	726	
5	97335:13:21:36	-41.0				
D	97336:20:24:03		1.0	1831.0	727	
6	97336:20:27:24	-21.0				
E	97341:16:44:50		-1.0	1830.0	726	
7	97341:16:47:57	51.7				
F	97345:19:15:53		-2.0	1828.0	724	
8	97345:19:18:15	70.0				
G	98013:12:21:32		2.0	1830.0	726	
9	98013:12:23:31	65.0				
H	98014:17:22:16		2.0	1832.0	728	
10	98014:17:23:48	-31.0				
I	98015:17:26:27		1.0	1833.0	729	* NO UTCF Adjustment
J	98020:13:16:57		8.0	1841.0	731	* NO UTCF Adjustment
K	98024:19:54:08		-26.0	1815.0	717	* NO UTCF Adjustment

Table 6.7-1 Clock and Frequency Standard Adjustments

Trending of the Frequency Standard shows that the temperature varies distinctively with the Beta angle (see Figure 6.7-3), fluctuating approximately 8°C. As with many other components, the FS reaches its warmest state when the Beta angle reaches its maximum (absolute) and is coldest when the Beta angle is 0°. It also shows a slight upward trend over time, increasing approximately 1°C per cycle (starts every second Beta=0 crossing). This is the same behavior seen from the other components of the SDS in that area, such as the Spacecraft and ACS Processors and Baseplate thermistor between them (see Thermal section, 6.9). The clock drift has also proven to be dependent on the varying temperature. The spacecraft clock toggles between positive and negative drift, turning around when the Beta angle reaches 0°. This is being trended to determine the boundaries of the drift by allowing the delta to reach +/- 900 μsec before adjustments are made.

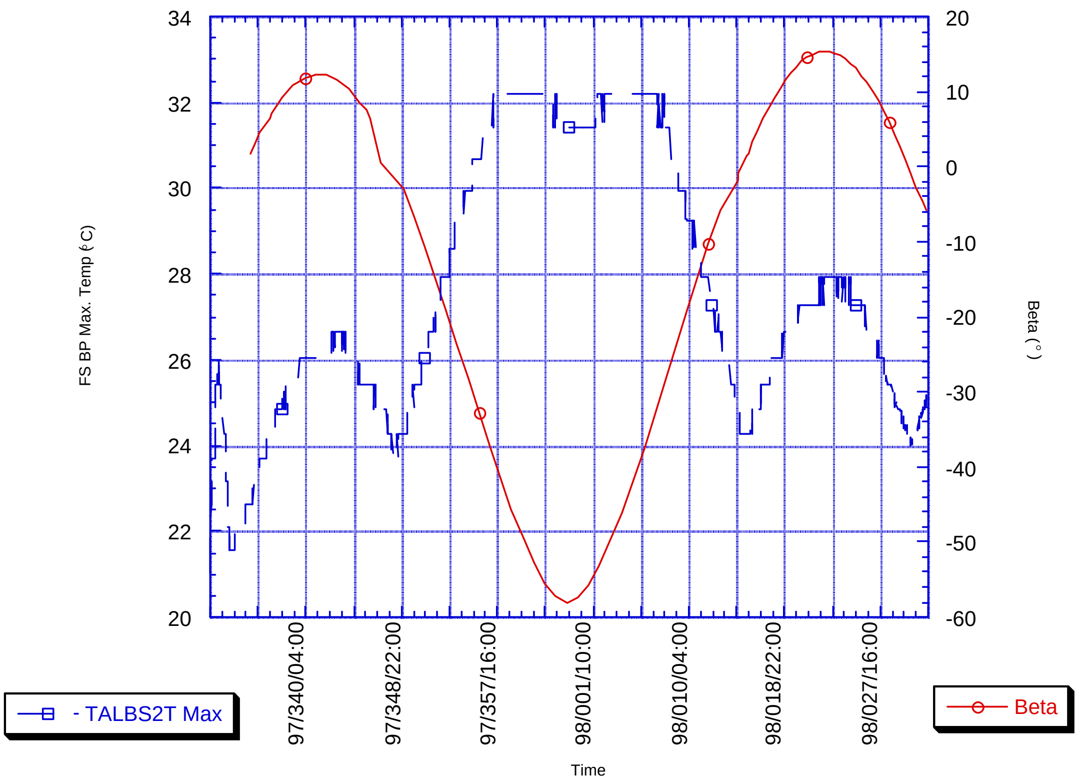

Figure 6.7-3 FS Maximum Temperature & Beta Angle

6.8 Flight Data System (FDS)

The Flight Data System has not shown any major problems in the first 60 days after launch and all capabilities have been checked out, including the new 4 and 8 kbps data rates.

The FDS software has detected several Software Bus (SB) events and one Framer (FR) event during the first 60 days. These events were caused due to the TMI and VIRS generating multiple packets with Invalid Stream Ids and are expected on occasion due to the behavior of the instruments. The VIRS error happens when a x'20' warning event is produced (Anomaly #26), and the TMI error occurs when the BCRT chip hangs temporarily (Anomaly #40). There was also an Unframing error experienced on 98-001 at 11:57. This was believed to be a hard error on the bus that was not detected by the 1773 hardware's Manchester coding but was detected by the FDS's FR frame validation (Anomaly #47). A similar hard error was seen on RXTE during bus-buster testing, but never on orbit.

Minimal changes were needed to reconfigure the FDS from launch to normal operations. The DS filter table (#68 and #69) defaults were loaded the first day after launch, once launch operations were considered successful, to stop recording the excess 8 Hz ACE-A data from the launch configuration. The normal operations flight quota table (#73) was loaded the second day after launch once the instrument checkout period began (to reconfigure for 215 minutes in each recorder). The EEPROM version of the ACE-B 1 kbps RTS (#7) was loaded on 97-335 to reconfigure to use the proper TO filter table (#2). On 97-363 the DS filter table was loaded to record Contingency Mode packets, and then reset after the testing. See Appendix D for a complete list of table loads performed since launch.

There also have not been many changes required to the Telemetry and Statistics Monitors (TSM) and Relative Time Sequences (RTS) with on-orbit data. TSMs #17 and #18, which turn off transponder 1 if left on for more than 40 minutes, were disabled on 97-348 during testing which required longer events, and then left disabled. This eliminates the time constraint when running with extended events. The original requirement was established because of power concerns, but since the Observatory has proven to have more than enough power, the concern is negated. TSM #29 was modified to trigger from the PSIB day/night transition, as opposed to time in night (Anomaly #43 - see VIRS section, 7.2). To provide extra protection, RTS #33 was changed to wait 30 minutes after returning VIRS to day mode before resetting the TSM. The RTSs which safe the spacecraft in the event that a new stored command load has not been uplinked (#127 and #128) were also changed to disable the transponder 2 turn-off TSMs (#19 and #20). This will allow for a constant downlink to acquire during the next event.

The Telemetry Output task has regularly experienced restarts (Q-Channel) due to the timing required to output a single frame (as opposed to the usual pair of frames). This occurs when performing playbacks and retransmissions during events because there is a higher probability of the single frame condition (Anomaly #29). This single-frame restart condition was encountered during CPT testing and an operational constraint was determined necessary to inhibit it. Since no data has been lost because of the restarts (see Appendix E for a plot and record of the Q-Channel Restarts experienced over L&IOC), the implementation of the operational constraint has been put on hold.

An anomaly has been experienced where the Time Code (TC) task of the spacecraft processor goes to FLYWHEEL mode for three seconds (one telemetry update), but no affect on operations has been observed to date (Anomaly #51). This has occurred nine times since launch, indicated by the time stamp of the APID #1 packet alternating between even and odd subseconds, and has not been experienced on the ACS processor. Tables #2 and #3 were loaded on 98-028 to dwell on the flywheel data to monitor for occurrences real-time. No other irregular behavior in relation to this with any other component has been observed. The cause has not yet been determined (see Appendix E for a summary of the flywheels).

6.9 Thermal Subsystem

The Thermal Control Subsystem (TCS) has operated in a normal and expected manner through the first 60 days since launch. While thermal variations have been observed, all temperatures have been well within allowable limits. For thermal performance on specific subsystems, see the related sections.

The biggest influence on the thermal behavior is the Solar Beta Angle cycle. Plots are provided in Appendix E to show the effects of beta angle on temperatures. Since TRMM has now experienced the full range of beta angle (0° to -58°), it can be shown how different systems react to temperature changes. The Beta angle cycle peaked at approximately -58° on 97-363, and reached 0° on 97-347, 98-014, and again on 98-029. Figure 6.9-1 shows the range of beta angles for the first 60 days after launch.

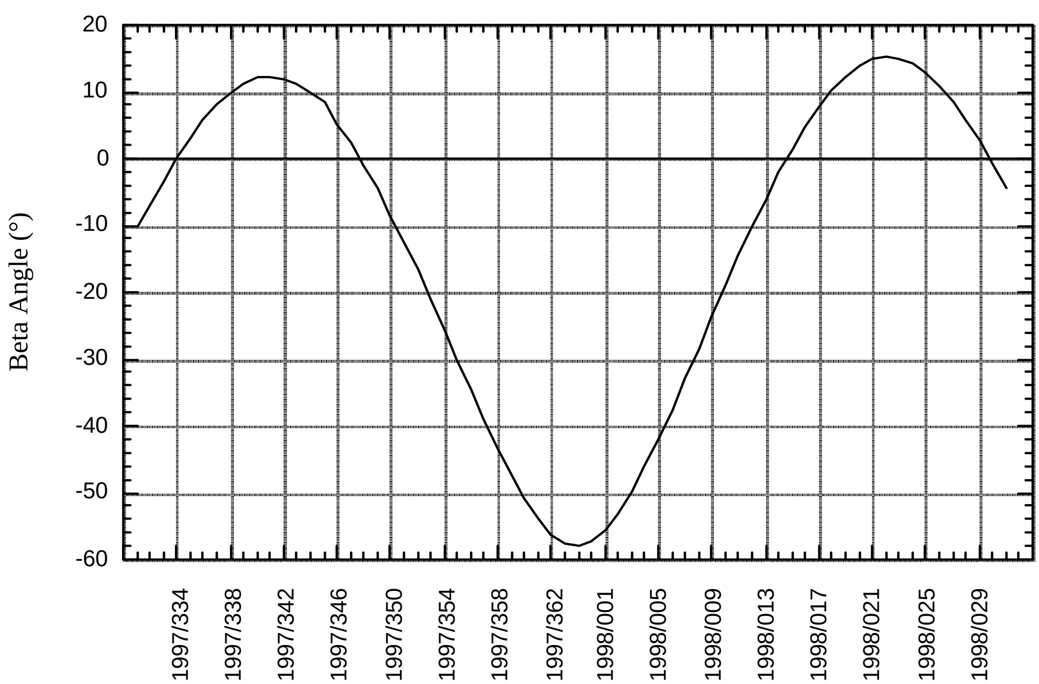

Figure 6.9-1 Beta Angle Over 60 Days

Location of boxes on the spacecraft is also a factor in temperature changes, especially in terms of heating by other components and by sunlight exposure.

Approximately as-expected temperature responses were observed during all of the instrument turn-on activities.

6.9.1 Spacecraft Maneuvers and Beta Angle Effects

The first real concern with the thermal subsystem occurred with the request to perform the first yaw maneuver about 2 days prior to reaching a Beta angle of -1° (the normal time to perform the maneuver). As a result, the Beta angle was approximately -5° when the spacecraft was initially commanded to the normal Earth acquisition attitude in the +X direction. Despite the fact that this resulted in solar loading of the normally anti-Sun facing side of TRMM, no adverse heating effects were observed, and all spacecraft and instrument temperatures were as expected. The battery temperatures were monitored closely during this period, since the battery louvers do not have a sunshade. Battery temperatures were relatively unaffected, and no significant trends were noted during this period.

On 97-347, the first 180° yaw maneuver was closely monitored for unusual temperature response, with none observed. The maneuver was performed in the Earth eclipse portion of the orbit.

On 98-348, a 90° yaw maneuver for calibration of the PR instrument was also closely monitored for unusual temperature response, again with none observed. This 90° yaw attitude, with the -Y side of TRMM flying into the velocity vector, was performed about 7 minutes prior to eclipse entry, which briefly allowed solar loading of the normally anti-Sun side of TRMM. Thermal engineers monitored the batteries, the +Y solar array drive motor, and the VIRS cooler (still with its cooler door closed, in Outgas mode, at that time), which were three of the items identified that could possibly be adversely affected by this event. No thermal response was seen with the batteries or the +Y solar array drive during this brief exposure. The VIRS cooler may have risen about 3°C during the Sun exposure, but was well within allowable limits (with the cooler in Outgas mode).

On 97-363, the maximum beta angle of -58° was reached. Battery temperatures were at their lowest during this period, with temperatures ranging between 5.8°C - 6.7°C and 8.8°C - 9.8°C, for battery 1 and 2 respectively. Refer to the plots in the Power Subsystem Section (Section 6.2) for more details.

CERES Deep Space calibration maneuvers were performed on 98-007 and 98-008, which put the Observatory into an inertially fixed orbit for 3 non-contiguous orbits on the 7th, and 3 additional orbits on the 8th. The VIRS cooler temperature was affected the most by this operation. Since the temperature of the VIRS cooler went above the normal limits, the outgas mode was enabled in order to read the maximum temperature which reached

162°C (see plot in Section 7.2). The cooler recovered into the normal operating range after the Deep Space Calibration maneuver was completed, although it is operating about 2-3°C higher then prior to the maneuver.

The only other thermal concern arose when the SAPY motor drive temperature approached a yellow high value. See the Deployables Section (Section 6.4) for more details on this subject.

6.9.2 Subsystem Thermal Plots

Appendix E shows plots of each of the subsystem thermistor temperatures. The Reaction Wheel Baseplate, SDS A and B Baseplates, and TMI temperatures are good examples of how most temperatures are affected by Beta angle, with increasing temperature coinciding with increasing Beta angle. Some baseplate thermistor temperatures, such as those for the Transponders, Power Amp 1, EVD, and ACE show an increase in temperature as the Beta angle increases, but a slight drop for a couple of degrees at the maximum Beta angle of -58°. The majority of plots show a sharp increase in temperature on 98-007 and 98-008 due to the CERES Deep Space Calibration maneuvers.

In summary, the Thermal Control Subsystem has operated in a normal and expected manner from launch through the first 60 days since launch. While expected variations have been observed, such as during the Deep Space Calibrations, all temperatures have been well within allowable limits.

7. Instrument Operations

Checkout of the instruments took place during the first 60 days of the TRMM mission. Science and calibration data collection began almost immediately upon power up for all instruments except VIRS. Once VIRS completed outgassing, it proceeded with science data collection. The following sub-sections describe the checkout activities and normal operations that took place for the period of this report for each of the five instruments on TRMM.

7.1 Precipitation Radar (PR)

From launch through launch plus 60 days, PR operated in an excellent manner. The PR instrument was launched in the Safety mode configuration in which power is supplied from the PSDU to the PR power supply relay, but the PR power supply relays are open. Only the A side survival heater relays were enabled so that the maximum possible heater current was reduced until TRMM was in a stable orbit. On day 2, one of the PR B side survival heater relays was closed, and the current draw was increased.

Checkout activities for the PR were performed according to the In-Orbit Checkout Plan (IOCP) as provided by NASDA prior to launch. The following paragraphs describe the checks that were performed along with the results of those checks.

IOCP-10A was performed to verify the thermal control function, power consumption, data processing software function performance 1a, and PR telemetry. The temperature change for each PR observation mode is shown in Appendix E. PR temperature is between the predicted hottest and coldest temperatures. The temperature gradient of the center panel is within 3°C, which is less than the specification value of 10°C. PR on-orbit thermal analysis was performed. Analysis condition is shown in Appendix E, and analysis results and the comparison with the flight data is shown in Appendix E. The difference between analysis results and the flight data is rather small, and it can be concluded that PR temperature will stay within the QT temperature throughout the mission life with sufficient margin. Power consumption on orbit is shown in Appendix E. It is within the specification of 250W, and coincides with the ground test data. The section regarding IOCP-51A discusses the data processing software function. S/C telemetry format check, including time tag check, comparison with HK telemetry value, and phase code check, was performed. All the checkout results were nominal.

IOCP-11A checkout items consisted of verification of the thermal control function in Safety/Low Power mode. Appendix E shows the comparison of the NASA thermal analysis results and the flight temperature data in the launch phase. Analysis and flight data values coincide well. Appendix E shows the PR temperature during safehold and low power condition in the L&EO phase. PR temperature is kept higher than the low limit, and the PR survival heater is working well.

IOCP-12A performed a trend evaluation and status verification of the HK telemetry and science telemetry. The resulting trend was normal. The PR telemetry status corresponded to the PR command operation in all cases.

IOCP-13A was a verification of limit checking of the level-0 data. During this check, a Phase code error of the H/K telemetry just after mode change from Stand-by to Observation, and system noise anomaly just after mode change from Analysis to Observation, were found. However, these phenomena occur in only one data scan just after mode change, and do not impact science observations. Another result was found when the TRMM S/C performed a Delta-V maneuver, where surface echo at the edge of the scan was often lost for about one minute just after the thruster burn. This is due to the S/C pointing accuracy reduction at this specific time when system noise over-limit occurred several times. In addition, surface echo receiving level at the nadir angle bin sometimes exceeded the dynamic range. In order to enhance the receiving level, it was decided to change the receiving gain from 6dB (default) to 9dB.

IOCP-21A provided verification of housekeeping and science telemetry and command. During this check, all PR commands were sent to the spacecraft and accepted by the PR. Telemetry/command function was normal.

Checkout item IOCP-31A provided a verification of PR performance by using the Active Radar Calibrator (ARC). Appendix E shows the checkout results summary. PR peak transmitter power, estimated by ARC receiving level and link calculation, coincides with PR peak transmitter power derived by SSPA TX power science telemetry and the ground test data with an accuracy of $\pm$ 0.6 dB. PR TX frequencies derived from the spectrum analyzer data also coincide with the ground test data. Appendix E shows PR TX amplitude weighting derived from SSPA TX power science telemetry which is normal. PR TX beam scanning in External Calibration limited scan mode was verified by ARC receiving level data. Appendix E shows along track TX antenna pattern. Beam width is 0.706 degrees with a normal antenna pattern. Appendix E shows along track TX/RX antenna pattern. The 6 dB down beam width is 0.73 degrees and the antenna pattern is normal.

IOCP-32A consisted of measuring the crosstrack TX/RX antenna pattern. Appendix E shows the measurement results and the analysis results. Measurement results agree with analysis results, and the 6 dB down beam width is 0.77 degrees.

Checkout item IOCP-33A performed a verification of minimum radar receive levels. Appendix E summarizes the checkout results. PR RX beam scanning in External Calibration limited scan mode was verified by PR data which shows the PR receiving level of the ARC CW TX signal. Appendix E shows along track RX antenna pattern. Beam width is 0.74 degrees and the antenna pattern is normal. Appendix E shows the estimated PR receiving level derived by measured ARC TX power and the link calculation, and the actual PR receiving level. For this calculation, revised FCIF calibration data is used. Taking the mean value of the six ARC TX mode external calibration results, it was concluded to introduce 1 dB bias error correction factor for calibrating PR receiving level. Appendix E shows the summary of PR minimum detectable receiving level. It was verified that PR has the capability of detecting 0.48mm/h rain from space.

Checkout item IOCP-34A verified precipitation echo and Earth's surface echo position. By the data shown in Appendix E, it was verified that the Earth's surface echo position was normal, as was the precipitation echo position. The range bin offset function was verified to be normal. Appendix E also shows that the beam scanning function of PR in Observation mode is normal.

IOCP-35A checkout consisted of verification of the Earth's surface echo position in Observation mode. When the TRMM S/C performs a Delta-V maneuver, surface echo at the edge of the scan is often lost for about one minute just after thruster burn. This is due to the S/C pointing accuracy loss at this time. Earth's surface is always included in the observation data, except during Delta-V maneuvers.

IOCP-41A checkout item consisted of an internal calibration. Appendix E shows the internal calibration data taken on orbit, and Appendix E shows the comparison of the on-orbit data and the ground test data. It was concluded that PR FCIF calibration shall be performed using IOCP-41A #1 internal calibration data.

Low Noise Amplifier (LNA) operations verification was performed in IOCP-42A. Appendix E shows the PR RX amplitude weighting data taken when PR was flying over the ocean in analysis mode. The weighting is normal and all the LNA's are healthy.

Verification of data processing software function performance 2 was evaluated with IOCP-51A. In IOCP-10, parameter alpha and beta were changed and the surface tracking performance was tested. It was concluded that the default value of the parameter alpha and beta is appropriate. However, during this test, lock-off of the surface tracking was found several times. In IOCP-51A, the gate width parameter was changed from the default value of 10 to values of 15 and 20. Communications Research Laboratory (CRL) is now investigating the data and will recommend the optimal gate width parameter value to be used in routine operations.

As described in the previous paragraphs, PR checkout was nominal for almost all checkout activities. Recommendations about the nominal operation of PR are included below as defined by NASDA.

- As mentioned above, it was decided to change the RX attenuator level from the default value of 6dB to 9dB. PR has been operating at the 9dB level since 98-033 at 23:30:00z with no problems. (Although this occurred after the 60 days had been completed, it is included in this report because it refers to the end of the PR checkout activities).

- Based on the initial checkout results, it is not necessary to use the range bin offset function.
- It is recommended that the internal calibration data shall be collected once per week. With this internal calibration, FCIF input-output characteristic (log amplifier slope and bias) is derived. Latest log amplifier slope values shall be used for level-1 ground data processing. When variation of the log amplifier bias value is larger than 0.6dB, it is recommended that an external calibration using ARC is performed, and that the bias error correction factor is updated as described in the section which discusses IOCP-33A. Internal calibration requests will continue to come to the MOC via TSDIS.
- For calibrating PR TX, external calibration using ARC RX mode shall be made. As stated in the IOCP-31A section, PR peak TX power, estimated by ARC receiving level and link calculation, coincides with PR peak TX power derived by SSPA TX power science telemetry. Therefore, unless an anomaly is found in SSPA TX power science telemetry, it is not necessary to perform PR TX external calibration.
- For calibrating PR RX, external calibration using ARC TX mode shall be made upon request to the MOC. This external calibration shall be performed at least once every two months or when the bias change of more than 0.6dB is found in internal calibration data.
- Cross-track antenna pattern measurements, performed with 90° yaw maneuver of the S/C, coincides very well with the analysis results. Cross track antenna pattern degradation is caused by the failure of SSPA, LNA or the div/comb 2 (phase shifter). Status of the SSPA and the LNA can be monitored by science telemetry. Analysis has shown that when one or two phase shifters fail, the impact to the cross track antenna pattern is rather small and is hard to detect by the ARC using a 90° yaw maneuver. Also, since performing the 90° yaw maneuver is a critical S/C operation, it is recommended that unless a severe anomaly is found to PR, it is not necessary to perform the cross track antenna pattern measurement with 90° yaw maneuver.
- Based on the initial checkout results, PR Instrument Orbital Operations Handbook (IOOH) and PR Instrument Operations Procedures (IOP) documents will be revised. The new versions will be available by the end of March, 1998.
- When a switch to PR B-side is required, minimum checkout items shall be performed. This is based on the policy to minimize the science data collection loss due to the B-side checkout activity. Checkout items IOCP-10B, IOCP-41B, and External calibrations should be included.

It was confirmed that PR status is normal, and PR satisfies its functional and performance requirements on orbit. In the initial phase, it was noted by the science side that the PR receiving echo level was higher than expected. Based on the external calibration using the ARC performed several times in December and January, calibration coefficients were updated and the PR Receiving Echo level is now well calibrated with respect to the ARC signal.

7.2 Visible and InfraRed Scanner (VIRS)

The VIRS instrument was powered ON on 97-334 at 12:48:01. The VIRS time-tag patch was installed immediately after VIRS was powered on. Since the VIRS scan drive was off, the subseconds for the VIRS telemetry packets were static. The initial power-on value for the subseconds field was all 1's, which represents a number of subseconds greater than one second and is invalid. This fooled the time-tag patch into thinking that the VIRS time anomaly was occurring and the patch then inhibited the update of the seconds portion of the time tag (Anomaly #21). The time-tag patch was then removed and was reinstalled immediately prior to turning on the VIRS scan drive. The VIRS time-tag patch is working as planned.

On the same day the Solar Shield Door was opened, the Radiative Cooler Door was opened to the Outgas position (approximately six degrees), and the instrument was commanded to Outgas mode. The cooler outgas operation was completed on 97-349. Outgas temperatures achieved with the radiative cooler door in the outgas position are shown in Table 7.2-1.

Cold “inner” stage	295 K (22° C)
Intermediate “outer” stage	304 K (31° C)
Mounting ring “Third stage”	308 K (35° C)

Table 7.2-1 Cooler Temperatures

After the outgas operation was complete, the outgas heaters were turned OFF, the instrument outgas mode was disabled, and the Radiative Cooler Door was opened for cool down. The cold stage temperature dropped below 130 K on the next day (97-350) and science data was received. The cooler temperature varies with solar beta angle. Estimated temperatures of cooler operation vs. beta angle from the initial cooler temperature data was from a low of 107 K (beta angle = -58°) to 111 K (beta angle = 0°). See Figure 7.2-1 of VIRS cooler temperatures plotted against beta angle for the first 60 days. The peak shown on 98-007 and 98-008 are due to the CERES Deep Space Calibration maneuvers.

On day 97-357, the first real-time occurrence of a VIRS invalid telemetry packet was seen (Anomaly #41). This symptom was seen during I&T and is due to a “double clock”, which causes a word of data to be skipped, and each remaining word to be put in place of the word before it until the end of the sequence. The invalid telemetry packets have not interfered with VIRS operations. These packets occur almost daily, however they are not usually seen during real-time.

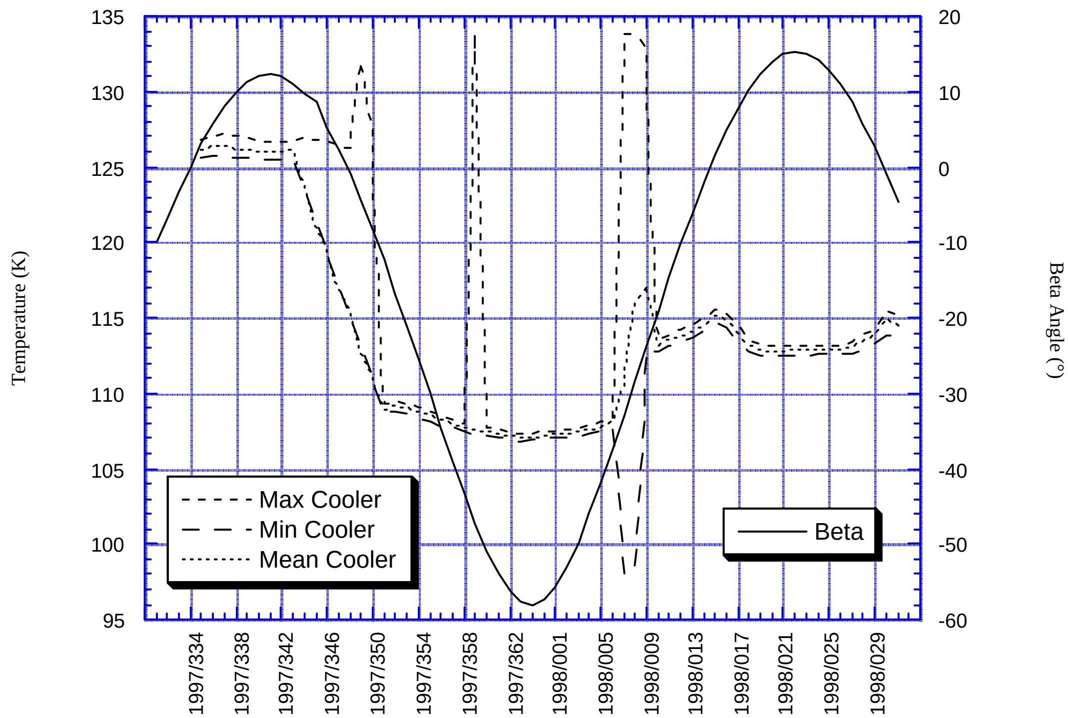

Figure 7.2-1 VIRS Cooler Temperatures and Beta Angle

Beginning on 97-359 through 98-003, TSM #29, which triggers VIRS Night mode, executed incorrectly and put VIRS into Night mode when it should have been operating in Day mode. (Anomaly #43). A total of 144 minutes of Channel 1 and 2 data was lost for that time period. TSM #29 was built to look at the PSIB 'time in night' data. If 'time in night' was less than 120 seconds for 3 updates, TSM #29 would trip. Since the PSIB was miscalculating 'time in night' (PSIB would calculate night for a couple seconds before transitioning back to day), the TSM was tripping when TRMM was still in day. Two things were done to correct this. First, the calculation of PSIB day/night transitions was adjusted (See Section 6.5 for details). In addition, TSM #29 was changed to look at the day/night transition, rather than the 'time in night'. The TSM currently triggers when the PSIB calculates that it is in night for 90 updates.

On 98-007 and 98-008 the Observatory was placed in an inertial orientation for three non-contiguous orbits on each day for CERES Deep Space Calibrations. Excellent data was obtained from the cold space scene viewed through the aperture during the first part of the first inertial orbit on each day. However, since the Earth Shield Door did not block the Earth heat input to the cooler during these orbits (due to spacecraft orientation) the Cooler warmed up above the temperature range of valid science data to a maximum cold stage temperature of approximately 160 K and an intermediate stage temperature of 185 K

(Outgas was enabled when the cold stage temperature reached 133 K in order to receive a valid temperature reading.).

The Radiative Cooler cold stage did not cool down to the temperature range achieved prior to the inertial orientation. The cause of the change in performance is attributed to a soft thermal short between the cold and intermediate stages caused by their relative close temperatures during the inertial orientation (185-160=25 Degrees). This can occur when the cold stage is not centered in the circular gap between the cold and intermediate stage. The increased heat transfer from the intermediate to cold stage keeps it warmer than when it is properly centered. The thermal short can be eliminated by warming up the cooler so that the cold and intermediate stages achieve the same temperature. When both stages are at the same temperature, there is metal to metal contact between the stages and the cold stage would be centered properly. Estimated temperatures of cooler operation vs. beta angle from the cooler temperature data after the inertial operation ranged from a low of 111 K (beta angle = 58°) to 115 K (beta angle = 0°). Cooler operation is still within the design operating range, however performance is improved at lower temperatures.

Instrument housekeeping data shows that all parameters (current, voltage, temperature, phase error, etc.) are within expected ranges. The scanner module blackbody temperatures are being kept within the 0° to 20° C calibration range by using the 8.5 W and 15 W heaters. The heaters are operated by ground command. Although the power supply temperature is normally within limits, it has operated up to 42° C (yellow high limit is 45° C), as shown in Figure 7.2-2. The power supply temperature can be reduced, if necessary, by reducing the use of the 15 W heater.

Warning flags (hex 2f, 78, 20, 30) are regularly received from the VIRS in telemetry. These are all warning messages that had been seen before launch and do not indicate any problem with the instrument, although they have been seen to coincide with spacecraft bus errors. Refer to Section 6.8 and Anomaly reports for more information related to the software bus errors.

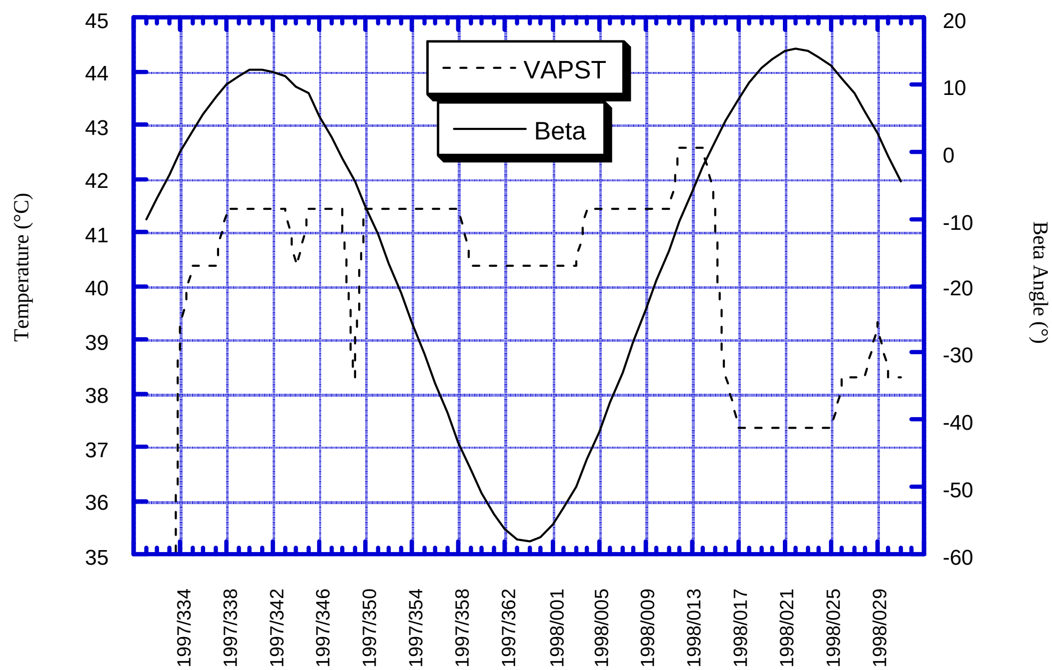

Figure 7.2-2 VIRS Power Supply Temperature & Beta Angle

Times and durations of VIRS solar calibrations that occurred in the first 60 days are shown in Table 7.2-2.

Time of Calibration	Duration
98-012/19:56:00	180 seconds
98-012/21:28:30	180 seconds
98-012/22:59:30	180 seconds
98-031/02:00:00	70 seconds

Table 7.2-2 VIRS Solar Calibrations

Overall, the VIRS instrument is operating as designed and excellent science data are being received.

7.3 TRMM Microwave Imager (TMI)

The TMI instrument sensor and antenna were deployed successfully on 97-331, at 23:17:35 and 23:23:26, respectively, taking 90 seconds and 45 seconds to deploy, respectively. Power was provided to the instrument at 23:25:29, at which time the antenna pyro deployment was verified. On 97-333 the instrument was commanded to mission mode by spinning up the sensor (at 14:35:25) and turning on the receivers (at 14:39:18).

TMI has remained in Mission mode, providing excellent science data, since power ON. There is some intermittent interference on the 21.3 Ghz channel (Channel #5 of 9 channels), which is still being investigated, but appears to be due to an intermittent attenuation in the coaxial cable that transmits the data from the 21.3 Ghz waveguide to its receiver, or its end connections. The problem can be correlated with solar beta angle, and is more prominent during high solar beta angles. The interference is apparently removed from the calibrated data since it appears in the cold load, hot load, and scene data.

A comparison has been made between the TMI and SSM/I (Special Sensor Microwave/Imager) science data temperatures on the common channels: 3 & 4 (19.35 Ghz vertical & horizontal polarization), 6 & 7 (37.0 Ghz vertical and horizontal polarization), and 8 & 9 (85.5 Ghz vertical and horizontal polarization). Data from channels 3, 4, 5, and 6 show a difference of up to 3°C. Data from channels 8 and 9 agree. The difference in channels 3, 4, 5, and 6 is being investigated but is not considered to be a concern. The TMI data will be recalibrated if necessary.

On 97-356, a software bus send error was received at 08:04:10 (Anomaly #40). At the same time, TMI did not put out any data for two scans. TMI housekeeping sequence counts 10578 and 10579 were skipped, as were two science packets, as indicated by the S/C payload manager. This is due to a known "timing conflict" within the TMI instrument and was predicted to occur once every sixteen days (Anomaly #40).

The TMI instrument is operating as designed except for the 21.3 Ghz interference and the slight data difference with SSM/I noted above. Excellent science data are being received from the TMI instrument.

7.4 Clouds and Earth's Radiant Energy System (CERES)

The CERES instrument is operating in the expected manner, without any instrument operational anomalies. There have been a few procedural glitches, but the instrument has responded as would be expected. There has been no indication of a stall condition with the azimuth gimbal, and the torque values have been nominal.

Early orbit checkout was completed without any functional anomalies, and the main contamination covers and MAM cover were opened on 97-361. A number of internal calibrations were performed both before and after main cover opening. The solar calibration procedure was run as a check prior to cover openings, and actual solar calibrations have been done since then, beginning on 98-004. Both internal and solar calibrations continue on a periodic basis. First operation of the instrument in Biaxial mode using S/C stored commands for Sun-avoidance was successfully accomplished on 97-364. A total of six orbits of CERES Deep Space calibrations were successfully accomplished on 98-007 and 98-008. Both internal and solar calibrations were done nominally on a daily basis for the next 10 days. On 98-019, CERES began its nominal science operational scenario of 2 days in Crosstrack mode and 1 day in Biaxial mode, with internal and solar calibrations performed nominally every two weeks on Wednesdays.

A few adjustments have been made to CERES database parameters, based on orbital data and performance observations. The range of the Sun elevation angles for which the CERES elevation gimbal is commanded to short scan has been opened up by 2 degrees (as of 98-002), 1 degree on each end of the range. CERES instrument temperatures since launch have been within the nominal range, with no limit values encountered. Monitored voltages have shown nominal values throughout the period.

There have been a few procedural glitches in the Sun-avoidance commanding. Analysis indicated that the normal Earth scan command was scheduled to execute too soon after exit from Sunrise, and a decision was therefore made to widen the Sun-avoidance zone. Current values of the upper and lower bounds are now +5 degrees and -23 degrees respectively. On 98-026, Sun-avoidance commands were scheduled using planning products that, by the day of command execution, contained data that was inconsistent with more recent planning products that were received prior to the day of execution. Analysis showed that the commands had been scheduled outside of the allowable Sun avoidance zones because of differences between the predicted, as given in the earlier planning product, and actual values of the CERES-unique Sun elevation angles. This did not lead to scanning the Sun or to safing the instrument because of the safety margin inherent in the wider Sun-avoidance zone. The CERES command generation process was modified such that days of Biaxial operations are scheduled using the most recent planning products, thus alleviating the large shift in predicted Sun elevation angles over time. This process has been verified since 98-026.

Analysis of CERES science data has been conducted since pre-launch simulations. Post-launch analysis of science data began as soon as the instrument was powered up on 97-337. Of particular interest were the early internal calibrations. As more science data has been analyzed, the LaRC Science Team members have been quite pleased with the results to date. The following enumerated comments are from Dr. Bruce Wielicki, Principal Investigator of CERES Interdisciplinary Science Team.

1. CERES instrument calibration checkout continues. Current understanding of early instrument results indicate that all instrument channel gains are within less than 0.5% of pre-launch ground calibration values. All scan position dependent instrument offsets are within less than 1 digital count of pre-launch values (Typically 1 digital count is less than 0.2% of signal level). Given these excellent initial calibration results, to our knowledge, CERES is the most accurate Earth-viewing radiometer yet flown in space. Further work may be able to push the consistency within 0.25%.

2. Tests of ERBE-Like Top of Atmosphere (TOA) Fluxes showed inconsistencies in albedo (some values greater than one) which were traced to an error in the calibration input file used in the operational processing stream. After correction, ERBE-Like fluxes passed initial QC checks. Work is now focusing on demonstration of whether the larger frequency of occurrence of clear-sky data for CERES/TRMM (than for ERBE) is consistent with the decrease in CERES field of view size relative to the coarser ERBE data. Work appears to be on track to provide a firm decision on LaRC/CERES ability to begin archiving of the ERBE-Like TOA Fluxes at the April 21-23 CERES Science Team meeting. If successful, this will be achieved one month ahead of plan.

3. One case of the CERES instrument detectors saturating under extreme sunlight conditions has been documented. Statistics are being generated to determine the frequency of occurrence of this condition. When it occurred, roughly three to four pixels of all three spectral channels were corrupted. These occurrences will be flagged as bad data in future runs.

4. Initial VIRS cloud imager data has been obtained, and off-line cloud property analyses are being made from VIRS data. Background clear-sky maps must be generated before significant cloud algorithm tests can be made.

5. Initial quick checks of the consistency of the VIRS channels showed good agreement with AVHRR (within 1 – 2 °K) for the 3.7, 11, and 12 μm channels. The visible channel showed significant differences (5 – 10%) with the GOES instrument. Results have been communicated to Barnes and Adler at GSFC. Awaiting word from GSFC on pre-launch versus post-launch onboard VIRS calibration.

6. Initial checks of the VIRS and CERES navigation accuracy appear to show agreement to within roughly 1 km, when compared to coastline maps.

7. An IEEE-IGARS Journal article on “CERES Algorithm Overview” has been accepted for publication (after minor revisions) in the IEEE EOS-AM special issue.

Data acquired during the Deep Space Calibrations have been extremely useful. Scan elevation-dependent offsets have been derived for each operational mode exercised during the calibrations. The offsets show excellent stability and are now being used in the operational software to interpret CERES instrument measurements.

Interested parties may view CERES information and quick-look results, including Top-Of-Atmosphere flux estimates and geolocation plots at the following LaRC CERES web site:

http://asd-www.larc.nasa.gov/ceres/trmm/ceres_trmm.html

7.5 Lightning Imaging Sensor (LIS)

LIS was powered ON at 332-14:52:40**.** Initially no science data was received because the Observatory was in 1kbps mode and LIS had not reached its operational temperature. During the first 60 days of operation, there have been no instrument failures or parameter limit violations since 97-332-19:37:37, which was during initial sensor warm-up.

In an effort to maximize the science data from LIS, the following threshold settings were sent to LIS during the first 60 days of TRMM's mission. Excellent science data is being received from the LIS instrument.

Command upload time	**Date**	**01**	**02**	**03**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
1998-022T21:58:24.47616	(Jan 22)	14	14	18	18	18	18	18	18	20	20	20	20	22	63	63	63
1998-022T21:57:10.94340	(Jan 22)	16	16	18	18	18	18	18	18	20	20	20	20	63	63	63	63
1997-353T22:31:46.07794	(Dec 19)	14	14	18	18	18	18	18	18	20	20	20	20	22	63	63	63
1997-352T19:01:28.16108	(Dec 18)	14	14	17	17	17	17	18	18	19	19	19	19	20	63	63	63
1997-352T17:05:36.47663	(Dec 18)	16	16	18	18	18	18	18	18	20	20	20	20	63	63	63	63
1997-349T22:46:10.86602	(Dec 15)	14	14	16	16	16	16	17	17	18	18	18	18	20	63	63	63
1997-349T22:46:10.86602	(Dec 15)	14	14	16	16	16	16	17	17	18	18	18	18	20	63	63	63
1997-332T14:53:18.13006	(Nov 28)	16	16	18	18	18	18	18	18	20	20	20	20	63	63	63	63

The instrument occasionally has a science data packet ready before TRMM is ready to receive it, (at one second intervals). This occasionally causes a packet to be missed. On 98-023, a sequence of commands to reset the instrument and reload the thresholds was sent to LIS. This minimized the number of packets that were missed. Regardless, the maximum number of science packets possible each day, 86400, are still being received.

7.5.1 LIS Science products

LIS science products and browse images are created routinely each day as data becomes available. Changes to LIS software filters continue including 1) change from earth located to pixel frame of reference for grouping events; 2) designing a new group to flash algorithm; and 3) improved noise filters. The flash algorithm developed for the LIS protoflight model, the Optical Transient Detector (OTD), is being modified as a result of the enhanced sensitivity and improved spatial resolution of the LIS. The enhanced sensitivity of LIS (over OTD) requires improved contrast (dark scene to bright cloud scene) filtering. After the new filters have been evaluated, the December-February science data will be reprocessed (planned for mid-March).

LIS data comparisons are being made with other TRMM sensor data. Geo-location looks very good. Two independent Houston storm overpasses are being examined. Software now exists which overlays the LIS data with PR, TMI, and VIRS. Sample data sets are on the LIS web page (http://thunder.msfc.nasa.gov).

DPREP (the ephemeris and attitude preprocessor software) orbit number calculation needs improvement. The current method calculates either one day or nine days of orbit numbers. With the exception of the receipt of one ED9D on 97-331, ephemerides were not received daily until 97-336. The problem was to determine the best way to create correct orbit numbers from the day of launch. The orbit number is part of the LIS science product granule file name. The V99 and V98 ephemeris data sets that were received early in the mission during the Delta-V maneuvers also created a problem, because the data did not start on a day boundary. DPREP will only process one day or nine day ephemerides.

Software was developed to create ephemeris and attitude information that could be processed with the Toolkit software. Several minor software problems were detected in DPREP. These problems were corrected and documented and forwarded to the developer.